C03879

Frontispiece.

Diser sehr grosse Joch = Geyer, hat Anno 1685. in dem Tyrol am Cirl Berg nahe
bey der Martins Wand auf disen Starcken Gemss = Bock da er auf einem Klepper
gang an einer Steilen Wand gestanden gestossen, das er bey 30 Klaffter hoch herunder ge =
stürzt und den hals gebrochen, da dann der Vogel bey dem raube auch geschossen worden.

J. El. Ridinger del. sc. et excud. 174

LÄMMERGEIER ATTACKING A STEINBOCK.

THE

HARMONIES OF NATURE

THE UNITY OF CREATION.

DR. G. HARTWIG

AUTHOR OF

'THE SEA AND ITS LIVING WONDERS' AND 'THE TROPICAL WORLD.'

WITH NUMEROUS WOODCUTS.

LONDON:

LONGMANS, GREEN, AND CO.

1866.

PREFACE.

HARMONY is the universal law of Nature. Of all the numberless forms of animals and plants that deck the surface of the globe, there is not one that is not perfectly fitted for its peculiar sphere. The configuration of our earth, and the physical laws that govern the waters and the atmosphere, are in complete unison with the wants of organic life; and suns and planets wander harmoniously through illimitable space. And as it now is, thus it ever has been; for the annals of our globe bear witness, throughout all the changes of the primeval world, to the concord which has constantly reigned between the physical condition of the earth and its inhabitants at each successive epoch.

In the following pages I have endeavoured to point out some of the most striking examples of this fundamental truth, which so forcibly proclaims the unity of creation. May I have acquitted myself of my task so as to strengthen my readers in the conviction that an All-wise and All-powerful Legislator has constantly presided over the destinies of the universe!

G. HARTWIG.

HEIDELBERG:
9th April, 1866.

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ERRATA.

Page 27, chapter head, *for* Ravines *read* Lavines.
„ 43, line 1, *for* first *read* firs.

THE

HARMONIES OF NATURE.

CHAPTER I.

THE STARRY HEAVENS.

The Setting Sun—The Splendour of the Starry Vault—The First Step to Astronomical Science—The Planetary System—How have we learnt to Measure its Dimensions?—Copernicus—Kepler—Newton—Laplace—The Planetary Perturbations reduced to Harmony—Discovery of Neptune by Calculation—Shooting Stars and Meteoric Stones—Their Composition—Spectral Analysis of the Sun's Atmosphere by Kirchhof and Bunsen—A Glimpse into the Fixed Star Heavens—Enormous Distances of the nearest Fixed Stars—Our World-Island—Nebulæ—Motions of the Fixed Stars—Vast Prospects into Space and Time—The Universal Harmony of Worlds.

THE SUN rests on the brink of the western horizon, sparkling over the ever-restless surface of the ocean. Dazzled by the excess of light, I turn my eyes from his brilliant orb and look down upon the strand at my feet, where the indefatigable tide-wave rolls upwards in broad sheets of foam, and then again falls back in a thousand little rills and with a thousand delightful murmurs.

My eye has rested, and once more wishes to enjoy the aspect of the setting sun; but the fiery globe has already sunk below the margin of the waters, to cast its streams of light over other lands and seas—to awaken millions to the labours and enjoyments of a new-born day. A gorgeous canopy of clouds, glowing in every tint of gold, scarlet, and purple over the evening sky, alone remains to bear witness to the vanished sun's magnificence—as after the death of a hero the memory of his deeds still lingers

behind in many a glorious tradition, and spreads a halo over his tomb.

At length even the last faint glimmerings of light have disappeared; night has fully vanquished day, and an increasing gloom seems about to cover all nature with a funereal pall. But this triumph of death is only apparent and of short duration, for as the darkness deepens, new worlds blaze forth from the dark heavens, and open the portals of the Infinite to our astonished gaze. Thus night, far from contracting our horizon, withdraws in reality the veil which hid from us the wonders of a boundless universe.

Who can describe the splendour of the starry heavens? With vivid colours the painter imitates the blushing morn or the moonbeam dancing on the lake; the forest, the sea, the mountains appear on his canvas like reality itself; but the wonders of the starry heavens mock the weakness of his art, for how could he confine the boundless fields of ether within the narrow limits of a painting?

In all times, in all zones, the aspect of the nocturnal firmament has awakened feelings of pious awe in the breast of man; and surely the idea of a single and omnipotent God first dawned in his soul while his eye was plunging into the depths of the skies, and star after star shone down upon him from that amazing dome whose cupola is everywhere extended and whose pillars are nowhere to be found?

The beauties of Nature are unequally distributed over the surface of our earth; some lands are gifted with all that can enchant the eye, while others are scenes of barren desolation: but the starry heavens are equally magnificent at the equator and at the poles, and wherever man exists their splendour is open to his gaze. But how many centuries may have elapsed before he *first raised himself from the admiring contemplation of this august spectacle to a more attentive observation of its mechanism*—before he first attempted to measure the orbits or to calculate the size of the celestial spheres!

The first step to a more accurate knowledge of the starry heavens was to ascertain the form and size of our earth, for it was thus only that a measure could be gained for the dimensions of the planetary system, a solid basis for the future development of astronomical science.

History teaches us that this first step was taken by the Greeks, who, judging from the facts that a vessel when coming from sea into port first shows the tops of her masts, and then seems to rise higher and higher out of the water as she approaches, that the sun rises later and later as we travel from east to west, and that the shadow of the earth, which appears during lunar eclipses on the surface of the moon, always shows a circular form, proclaimed its spherical shape, and even made the first attempts to measure its size.

But as their geographical knowledge was very limited, and their instruments of measurement imperfect, their calculations could not but be extremely defective; and thus it was reserved for later times to ascertain that the earth is a globe flattened at the pole, with an equatorial diameter of 6,864, and a polar diameter of 6,852, geographical miles.

The dimensions of the earth being thus known, it was now a comparatively easy task to measure the distances of the various planets belonging to our Solar System; for the mathematician requires but to know the length of a line, and the angles which its extremities make with a third point, to obtain a full knowledge of the dimensions of the triangle thus formed, and consequently of the comparative distances of all its parts. With triangles he invades the celestial space and subjects them to the dominion of science, as surely as by means of triangles he measures the extent of his fields or the height of his mountains.

By this means it has been calculated that the moon is about 208,000 geographical miles distant from the earth, while the sun sends us his enlivening rays from a distance of 80,000,000 miles: and thus we know that while torrid Mercury, the planet nearest to the sun, revolves at a distance of 32,000,000 miles from his orb, frigid Neptune receives his scanty supply of warmth and light from the amazing distance of 2,800,000,000 miles!

According to the delusive testimony of our eyesight, the sun and all the planets move round our earth, as if it were the centre of the universe. We see the sun and moon rise and set, and the stellar canopy slowly revolving round the Polar Star. But we seem to repose in majestic immobility, and thus it appears as if all those luminous worlds acknowledged the supremacy of our globe and paid homage to its superior power.

For thousands of years Science itself remained enthralled by these delusive appearances, until at length the master-mind of Copernicus reduced our planet to the rank of an humble follower of that sun which it had so long appeared to rule.

This great man first convincingly proved that the sun does not revolve round the earth, but that we and all the planets circle round the sun; and that the earth, by turning on her axis every twenty-four hours from west to east, produces that apparent movement of the starry heavens from east to west which had deceived all previous astronomers. Where formerly darkness and error prevailed, and the most ingenious and complicated hypotheses had been unable to explain the intricate motions of the planets, the mystery was now solved at once in the clearest and most simple manner.

Building still further on the Copernican system, the illustrious Kepler next showed that the planets do not move in circles but in ellipses round the sun, and discovered the laws which regulate the swiftness and proportions of their orbits. Twelve years after this great man's death our immortal Newton was born, who proved that the movements of all the celestial bodies flow from the supreme law of universal gravitation, or the mutual attraction of bodies according to the proportion of their masses and distances.

By means of this fundamental law—which regulates the movements of the stars as well as the fall of terrestrial bodies, the course of waters, the motions of the pendulum, and the direction of the load-line—it was now possible to solve many most difficult problems, which until then had baffled the sagacity of the greatest mathematicians and astronomers, to explain the precession of the equinoxes, to determine the weight and the *masses of the various bodies of the solar system, and finally to* calculate the *perturbations* resulting from the mutual attractions of the planets.

The word *perturbation* might possibly lead us to fear, that at a period however remote the laws which maintain the planets in their course might ultimately be overcome by counteracting forces, and an irreparable catastrophe be the consequence; but the calculations of Laplace have proved that all alarms on this subject are perfectly groundless, for the planetary perturbations are as subject to eternal laws as all the other motions of the

heavenly bodies; they never exceed a certain limit, they mutually correct each other, and cannot possibly become dangerous. Thus, by an admirable mechanism worthy of the Supreme Architect of worlds, even the deviations of the planets contribute to the eternal harmony of the spheres.

When Herschel discovered Uranus, that dim planet, which receives the faint rays of the sun from a distance of 1,600,000,000 geographical miles, it was supposed that the utmost limits of our solar system had been attained, and that beyond must begin the vast solitudes which separate the dominions of our sun from those of the nearest fixed star. But Uranus showed perturbations in his path, which could not be accounted for by the attraction of Saturn, and could therefore only be ascribed to an unknown planet. The calculations of Le Verrier determined the position and the mass of this new celestial body; and scarcely had he pointed out the spot where, according to all probability, it must be revolving through space, than the telescope of the Berlin astronomer Galle verified the accuracy of his statements, and discovered Neptune circulating as a star of the eighth magnitude, 2,800,000,000 miles from the sun.

Truly a splendid triumph of mathematical science, a magnificent victory of the human mind, thus to calculate the existence of an unknown world, and to see, as it were by the light of reason, what no human eye had ever beheld!

Possibly other planets may still roll beyond Neptune, which perhaps no telescope will ever be able to detect; but from the perturbations they may cause, their existence will be as evident as if we could follow them on their lustrous path.

Besides the planets and moons and numerous comets, a vast number of smaller planetary bodies, partly disseminated, partly grouped in annular zones, revolve on elliptic orbits round the sun. When these small planetary bodies come within the sphere of the earth's attraction, they obey its influence, and, darting down, give rise to the phenomena of shooting-stars and meteoric stones.

On a bright night twenty minutes rarely pass, at any part of the earth's surface, without the appearance of at least one meteor. At certain times (the 12th of August and the 14th of November, when in all probability our earth crosses the orbit of one of those annular zones) they appear in enormous

numbers. During nine hours of observation in Boston, when they were described as falling like snowflakes, 240,000 meteors were calculated to have been observed. The number falling in a year might perhaps be estimated at hundreds or thousands of millions, and even these would constitute but a small portion of the total crowd of asteroids that circulate round the sun. As these bodies, while obeying the earth's attraction, traverse our atmosphere with planetary velocity, they would no doubt cause a terrible bombardment, and from their vast numbers render our planet absolutely uninhabitable, if their very speed had not been made the means of neutralising their otherwise disastrous effects: for, raised to incandescence by the atmospheric friction engendered by this enormous velocity of from eighteen to thirty-six miles a second, by far the greater portion of the aërolithes are dissipated by heat, and a small number only reaches the surface of the earth under the solid form of meteoric stones.

Interesting by their celestial origin, these masses are still more so as the only *tangible* and *ponderable* proofs we possess of the material existence of a world beyond our own—as teaching us that the substances of which our earth is composed exist also beyond its limits: for the chemist finds the meteoric stones composed of iron, nickel, cobalt, silica, aluminium, and other terrestrial elements, nor do they contain a single atom of any substance that is unknown to us on earth. This circumstance sufficed to render it very probable that our whole solar system has been constructed of identical materials; but the wonderful researches of Bunsen and Kirchhof have raised probability to certainty, by proving that sodium, calcium, magnesium, chromium, iron, and other metals are constituents of the solar atmosphere and of the sun's central orb.*

However vast the scale of our planetary system, however incapable our imagination may be to grasp its immensity, it still forms but a minute portion even of the visible universe; for how insignificant in point of numbers, size, and distance are all the satellites revolving round our sun, in comparison to the countless hosts of the sidereal heavens! So enormous are their distances, that the immense diameter of the earth's orbit, as

* The reader will find an excellent account of the experiments which led to this brilliant discovery in Professor Tyndall's admirable *Lectures on Heat*, pp. 408–415.

seen from them, is only an indivisible point; and it is only within the last few years that instruments of a precision unknown to former ages have at length brought a small number of them within the reach of human calculation. In these immense regions of space solar orbits are too small to serve as a unity of measure; we are obliged to travel on the wings of light, which in a second leaves 200,000 miles behind, to be able to express, in a few numbers, distances which exceed the utmost limits of our conception.

A ray of light emitted from our earth would require three years and a half to reach the nearest fixed star; twenty years long it would have to dart through the fields of ether before it reached Sirius, and thirty years would have to pass before it rested on the Polar Star.

Thus the distances of about thirty of the nearest fixed stars have been measured; but the remaining thousands which we are able to see with the naked eye, and the millions which the telescope reveals to our gaze, roll on at such immense distances from our planet, that most probably no progress of astronomical science will ever be able to bridge over the intervening gulf. A reduction of stellar distances to a smaller scale will enable us to form some faint idea of the enormous difficulties of their calculation, and of the astonishing perfection of our instruments. Supposing the sun to be of the size of an orange, and placing it in the centre of the dome of St. Paul's, our pea-sized earth will then be performing its orbit within the circumference of the dome, while Neptune will be moving in the vicinity of the Bank, and many of the comets extending their vagrant excursions as far as Charing Cross. From these proportional distances we may easily conceive how, the diameter of the cathedral dome (which is here supposed to be the diameter of the earth's orbit) being known, it must be comparatively easy to measure all the angles necessary to calculate the distances of Neptune or any other planet: but when we come to consider that, according to the given proportions, the nearest fixed star would be sending us its light from the vast distance of St. Petersburg, then indeed we must be astonished at the perfection of the instruments which from so narrow a basis have been able to measure the all-but-imperceptible inclinations of the angles verging towards that distant world.

Before Bessel made the first successful attempt to determine the distance of a fixed star, Sir John Herschel had already taken the first steps towards the conquest of the sidereal heavens. Through telescopes of an increasing range, he saw with their growing power the number of the stars increase that presented themselves before his field of vision, and thus gained a measure for the form and the dimensions of the stellar system to which our sun with all his satellites belongs.

This amazing cluster of worlds—this our 'world-island,' as it has been appropriately called by Humboldt, consisting of all the constellations seen with the naked eye, and of the unnumbered stars that glimmer in the Milky Way—is of a lenticular, flattened, oblong, or elliptic form, and swims like a prodigious archipelago in the unmeasured realms of space. We know the immense distances that separate us from the nearest fixed stars, and can thus form a faint conception of the vast dimensions of a group composed (according to Herschel) of at least twenty millions of self-luminous stars. It has been calculated that a ray of light would require at least six thousand years to measure it from end to end, and fourteen hundred years to traverse it in its breadth. But even this amazing group of stars, vast and colossal beyond the bounds of human imagination, forms but a point in the universe, for on all sides similar clusters are seen looming out of the depths of the skies at distances to which that of Sirius from the earth dwindles down to one of our terrestrial measures. Many of these clusters, which are either entirely invisible to the naked eye, or appear only as nebular spots on the dark background of the celestial vault, require Lord Rosse's great telescope to be dissolved into their component stars; while others resist even this powerful test, *and continue to appear as specks of mere luminous matter.*

Hitherto it was supposed that the immensity of their distances alone prevented them from being dissolved; but the true nature of some of them at least has been fully established by recent investigations, which, by extending Bunsen's and Kirchhof's solar discoveries into the world of the fixed stars, have not only been able to prove that the glowing atmosphere of Aldebaran, for instance, contains quicksilver, and that of Sirius antimony, but that many of the nebulæ are in reality but immense gaseous bodies, which we may suppose to be new

worlds in the course of formation—worlds destined after incalculable ages to become the seat of sensitive and rational beings.

At the beginning of the present century, the *fixed stars, our sun among the rest*, were still supposed to be immovable, since, as far as our astronomical annals reach, no change has ever been observed in their mutual positions; but the wonderful precision of our modern instruments, and the progress of astronomical observation, have taught us that they by no means deserve their name. As we and all our brother-planets are circling round the sun, thus also the sun with all his satellites careers through space at the rate of 800,000 miles a day; but the time of observation is as yet too short to be able to ascertain the centre of his prodigious orbit. Similar motions have been discovered in other fixed stars, and thus we can hardly doubt that all the spheres of our world-island are engaged in constant motion—nay, that our world-island itself revolves round another, and that thus eternal motion pervades all the recesses of the universe.

The enormous swiftness of the fixed stars gives us an overwhelming idea of the vast proportions of the starry heavens. Every minute they leave several hundred miles behind—every minute we are carried along with the sun at the same prodigious rate through the celestial regions; and yet the starry firmament appears constantly unchanged, as it did to our fathers before us.

This boundless prospect *into space* opens to us a no less boundless vista *into time*, for the sight of the distant heavens does not exhibit their *present* but their *past condition*. The rays of light which bear witness to the existence of these worlds, circling in their unfathomable depths, have many of them required millions of years to reach our planet. Many of those brilliant orbs might have become extinct ages ago, and yet their rays, sent forth up to the moment of their destruction, would still announce their past glory to countless worlds. Thus with every improvement of the telescope not only the *magnitude*, but also the *age*, of the visible universe increases; and as we dive deeper and deeper into the abysses of celestial space, we also plunge deeper and deeper into the ocean of the past. And if we could fly to those islands of light, which even our giant telescopes are scarce able to reveal, we still should be only on

the threshold of new worlds; and how far should we have to fly before we reached the regions of formless void, if such there be! So much is certain—that all we can see is but as a speck in the immensity of the creation, as our earth is but a speck in the solar system, and the solar system itself but an imperceptible atom in the stellar cluster of which it forms a part. The vastness of the universe may well overpower the weakness of our comprehension—well may we feel humbled to the dust on comparing our utter nothingness with the amazing grandeur of the surrounding world; but our heart soon recovers from its depression at the consoling reflection, that the same bounteous Father who instilled into us the breath of life, maintains all this vast universe in constant harmony and beauty. As the planets revolve in regular orbits round the sun—as the comets, however far they roam in their erratic course, are yet obliged, in obedience to the law of gravitation, to return to their central orb—as, within the comparatively narrow confines of our solar system, the beautiful spectacle of order, regularity, and unity strikes us in every detail, thus also we cannot possibly doubt that the same order, the same harmony, the same unity of plan pervades all the unknown recesses of the universe, and that the whole of the amazing structure proclaims in all its parts, throughout all time and space, the infinite power and wisdom of God!

CHAPTER II.

HEAT AND LIGHT.

The various Sources of Heat—Effects of Heat—Dependence of Terrestrial Life on the actual Distance of the Earth from the Sun—Relations of the various Bodies to Heat—The Prismatic Colours—The Harmony between Colours and the Human Mind—What is Heat?—What is Light?—Importance of the Ethereal Spaces with regard to the Distribution of Heat and Light.

SNOW covers the fields, the rivulets are ice-bound, the wintry blast howls through the leafless forest, and at an early hour the languid sun veils his weak rays behind the mists of the western horizon. The songsters of the groves are mute, the insect tribes have disappeared from the face of the earth, and every freeborn animal seeks shelter in burrows or in caves.

Thus all nature seems to sink into lethargy and death—but a wonderful resurrection is at hand. The sun rises higher and higher in the skies, with every returning morn he gilds the purple east sooner and sooner; every afternoon he disappears later and later to spread his floods of light over another hemisphere—every day bears witness to an increase of his power. The melting snow descends in a thousand rills from the mountains, and the river, overflowing his banks, rushes with all the energy of youthful liberty through the resounding valley. All the dormant germs of organic nature burst forth in an endless variety of forms: the naked forest clothes itself with a fresh robe of verdure, thousands of flowers enamel the fields, thousands of birds sing, and numberless insects buzz or dance in the balmy air, and the wild denizens of the woods wander through the thickets in the full enjoyment of freedom.

The heat of the sun is the wonderful agent of all these various scenes of activity and happiness; but the sun is not the only source of heat, which may also be developed in a variety of ways from all terrestrial bodies. Friction heats our

iron tools, and savage nations usually make fire by rubbing two pieces of wood against each other. Percussion and compression likewise produce heat. A cannon-ball, on striking a thick sheet of iron with full force, will instantly raise its temperature to red-heat; and on suddenly compressing air to about one-fifth of its previous volume it will set fire to cotton. Electricity, chemical changes, the process of life, are also generators of heat; it rises out of the craters of volcanoes, or gushes in thermal springs from the bowels of the earth.

A very general effect of heat is its expanding force. With a few remarkable exceptions, it universally appears as the mighty opponent of cohesion, as the adversary of terrestrial attraction. First it increases the volume of solid bodies, then it reduces them into a liquid state, and finally converts them into gases—a phenomenon which no other agent is capable of producing. Hence the state of cohesion of all bodies solely depends upon their temperature. Placed at a different distance from the sun, our earth would offer a very different aspect: if considerably nearer, enormous quantities of water would constantly be volatilised, and then again precipitated in terrific showers; if far removed, the sea itself would be converted into a solid body, and the circulation of fluids, the prime agent of vegetable and animal life, be arrested. Thus our existence depends upon the degree of heat resulting from the *actual* distance of our planets from the sun; and as we cannot possibly attribute our origin to chance, thus also it is surely not this blind capricious power, but the allwise providence of a Supreme Being, which, myriads of years before the breath of life was instilled into man, determined the distance of the earth from the sun, that it might one day become his residence.

If, as is by no means improbable, Mercury and Venus or Jupiter and Saturn are the abodes of rational beings, these must inevitably be very differently formed from us, as they dwell on planets where all the conditions of organic life are so totally different; but as harmony reigns everywhere on earth, we cannot doubt that, whatever their form, they will in every respect be as perfectly adapted to their various abodes as we to our terrestrial habitation.

With respect to their relations to heat, we find a remarkable difference in various substances or bodies. Some change their

temperature with great rapidity, others but slowly; some are good, others bad radiators of heat; some absorb it greedily, others allow it to pass freely through their molecular tissues. Thus the sun brings forth an infinite variety of actions and reactions on the surface of the earth, for the atmosphere, the waters, the solid parts of our globe are all variously affected by his rays; and as all bodies are constantly endeavouring to equalise their temperatures, it may easily be imagined what numberless interchanges of heat are constantly taking place in all directions over the surface of the globe. But from these perpetual oscillations, from this restless striving towards a uniformity of temperature which can never be obtained (for not a cloud passes, not a sunbeam falls, without creating some new disturbance), arises that magnificent harmony between organic life and the external world of air, water, and earth, which can only have resulted from the design of a supreme regulator.

If a beam of pure white light, admitted through a small hole in a window-shutter into a darkened room, be made to pass through a triangular prism of glass, it will be disentangled and reduced into a number of splendid colours, similar to those exhibited by the rainbow in all its beautiful gradations of red, orange, yellow, green, blue, indigo, and violet. These primitive tints, which are also called elementary or simple colours, as they are incapable of any further division, will reproduce colourless light, if concentred on one spot by a lens—a proof of their being its component parts.

If the light of the sun were simple, then all bodies would appear to us either black or white, by the absorption or reflection of its uniform rays, and thus Nature, instead of her wonderful and many-coloured garb, would offer but a few dull and monotonous tints.

As, however, but few bodies reflect or absorb the entire sunbeam, while the majority retain only a part of the prismatic colours and reject the remainder, which thus become visible to the eye, that charming variety of colours is obtained, which we admire in the glowing purple of the morning and evening sky, in the brilliant reflections of the sea, in the foliage of the trees, in the hues of flowers, in the splendid robes of the animal creation, or in the lustrous tints of the mineral world.

The immense variety of colours with which the face of Nature is adorned, not only affords the fullest gratification to our sense of the beautiful, it is even essential to our very existence, and to that of most of the higher animals; for how should we be able to find our food, or to escape from our enemies, if all objects were uniformly black or white? Plunged in a colourless world, man could never have become a civilised being; his fancy, his knowledge would have been crippled, his mind torpid and inert. Thus there is an intimate harmony between the coloured sunbeam and the wants of our spiritual nature, evidently proving that both proceed from the same divine source.

The successful investigation of the properties of light is one of the proudest triumphs of human ingenuity. Light darts through space with an utterly inconceivable rapidity, yet man has been able to measure its speed. He knows that it undulates at the rate of 192,000 miles a second, and that as no less than 39,000 waves of red light and 57,500 waves of violet light placed end to end would be required to make up an inch, the vibrations of the former within that minute space of time amount to the truly astounding number of 474, and those of the latter to 699, millions of millions!

In passing through various media, or on striking their surfaces, light is refracted or thrown back in angles of every dimension; yet man reduces all these deviations to fixed laws, and calculates them with mathematical precision. He knows whether light proceeds from a self-luminous star, or whether it is only reflected by a planet—and thus obtains a measure for the various natures of the celestial bodies.

To be able to make all these discoveries and observations, to be able to track light to inconceivable distances, or to penetrate by its means into the secrets of the microscopical world, he has armed his limited eyesight with truly magical instruments, which reveal to him both the existence of distant worlds and that of creatures so minute that many thousands find room for their activity in a single drop of water! Within the last few years he has even forced light to do him service as a painter, and to trace portraits or landscapes with a delicacy and perfection of touch such as the human hand would vainly strive to emulate.

What is heat?—what is light? These questions, so difficult to

CHAPTER III.

THE ATMOSPHERIC OCEAN.

Immensity of the Atmospheric Ocean—The Component Parts of the Atmosphere—Oxygen—Nitrogen—Wonderful Constancy in the Composition of the Atmosphere—Antagonism between Vegetable and Animal Life—The System of the Winds—Dependence of all Terrestrial Life upon the actual Constitution of the Atmosphere—Atmospheric Air but a Mixture—No Chemical Combination of Oxygen and Nitrogen—Transparency of the Air—Its Influence upon the Mental Development of Mankind—Air considered as the Bearer of Sounds—Voices of Nature.

OVER sea and land spreads the vast cupola of the atmospheric ocean. You might fly twenty times higher than ever the condor flies, you might pile fifty Mont Blancs one upon the other, and yet you would not reach its confines.

In wondrous majesty the sea rolls its billows over three-fourths of the surface of the globe, and the plummet has not yet revealed to us all the mysteries of its depths; but even the sea is small, when compared with the vast domains of air that rise above it to an unknown height.

Of what substances is this immense aërial ocean composed? It was a highly important step in the progress of human knowledge when this question was first answered, when towards the end of the last century Lavoisier first discovered that the air we breathe is not a simple elementary body, but a mixture of two gases of very different properties, to which he gave the names of oxygen and nitrogen.

As is well known, the first of these gases, which forms about a fifth part of the volume of the air, is extremely combustible, and has a great tendency to combine with other bodies; while nitrogen, which occupies the remaining four-fifths of the volume of the atmosphere, is incombustible, and but little inclined to sacrifice its independent existence; and thus, while oxygen enters largely into the composition of water, and of most of the substances which form the solid earth-rind, nitrogen is chiefly confined to the aërial regions.

All organised beings absolutely require oxygen for their existence, and receive it from the inexhaustible sources of the atmosphere. When we reflect on the countless millions of animals which are constantly inhaling and consuming this prime necessary of life, and as constantly evolving carbonic acid, a gas destructive to life, we well may wonder how, in spite of this enormous consumption and perpetual pollution, the composition of the atmosphere still remains unchanged from age to age.

This immutability in the midst of eternal disturbance, this constancy where so many changes are perpetually at work, can only be the result of a wonderful order, of a masterly balance between conflicting influences.

The opposite wants of animal and vegetable life are the chief means which Providence uses for maintaining the purity of the atmosphere. Animals consume oxygen and exhale carbonic acid, while in the economy of plants the inverse operation takes place. Thus, without the plants, the animals would soon decline and perish, in consequence of the increasing impurity of the atmosphere; and, on the other hand, the plants could not exist without the carbonic acid, which the vital process of animals is constantly imparting to the air.

Even in the narrow space of an aquarium we are able to perceive the beneficial effects of this opposition between vegetable and animal respiration. For if we enclose marine animals alone —mollusks, annelides, star-fishes, crustaceans—in one of these reservoirs, they soon perish, in consequence of the want of oxygen and the pollution of the water; but by adding a few plants— ulvæ or confervæ—the equilibrium maintains itself, and while the latter enjoy a vigorous growth, the former are able for a long time to preserve an unimpaired health.

Yet, in spite of this admirable antagonism between the vegetable and animal kingdoms, the purity of the air would have been but imperfectly maintained if the atmosphere had not been kept in a state of constant motion by the magnificent system of the winds, which force the air to wander in perpetual currents from the equator to the pole, and from the pole to the equator.

The unequal influence of the heat of the sun upon the atmosphere between the tropics and in the higher latitudes is the first grand cause of this immense aërial circulation. In those favoured regions where the sun darts his vertical rays upon the

earth, and pours floods of warmth into the bosom of the ocean, the rarefied air, as if attracted by the great luminary, ascends in vertical columns to the skies. But as the law of gravity tolerates no void, cold air columns keep constantly rushing in from the poles to replace the ascending equatorial air-currents, which, on reaching the higher regions of the atmosphere, in their turn gradually descend towards the poles, where, condensed by the cold, they again resume their equatorial migrations.

While the sun thus perpetually ventilates the air on a truly magnificent scale, the unequal warmth of the various bodies which clothe the surface of the earth likewise causes a constant agitation of the atmosphere. Grass, stones, the leaves of the forest, the waters, are all unequally heated by the sun, radiate with unequal power the caloric they have absorbed, communicate to the contiguous air a higher or a lower temperature, and consequently a diminution or an increase of weight. But the air constantly strives to restore its equilibrium, and thus sweeps along in constantly renewed currents over the surface of the bodies which cause these constant perturbations.

The carbonic acid which we exhale with our warm breath is carried to a distance before our breast expands for a new inspiration, and, in the open air, not a single atom that has ever escaped our lungs will again return into their cells. Thus the sun, the source of light and warmth, is also one of the chief promoters of our health.

The organisation of all plants and animals is so intimately based upon the existing composition of the atmosphere, that, supposing a change to take place in the constitution of the air, all beings actually existing must necessarily perish. If the atmosphere contained a greater proportion of oxygen, the current of our life would be accelerated for a time, but would also be much more rapidly consumed; and if, on the other hand, its quantity was considerably reduced, the respiratory process would languish, and life soon become extinct.

The petrified remains of birds and quadrupeds which we find in the deposits of the primeval ocean prove that during an incalculable series of ages the composition of the atmosphere cannot have differed in any notable degree from its present condition, but they prove at the same time how perfect the laws must be, which during such vast periods have constantly maintained its uniformity.

It is a highly important fact that the air we breathe does not consist, like water, of an intimate combination of elements, but only of a mixture of gases which are not united together by the close bonds of chemical affinity. The reduction or separation of a compound body—whether solid, liquid, or gaseous—into its component parts is in every case the more or less violent disruption of a more or less intimate association, and consequently cannot be effected without the waste or consumption of a certain amount of power. Thus we see how greatly the respiratory process of animals is facilitated by their being able to obtain their supply of oxygen, without first being obliged to separate it from an intimate connection with its accompanying nitrogen, which, going in and out of the lungs unchanged, merely performs the passive but highly important part of moderating the action of its fiery partner.

The air of the atmosphere not only contains the substance which our vital process absolutely requires for its maintenance but its physical properties have likewise been made to harmonise most beautifully both with the existence of organic life and the development of our mental powers. What would have been the consequence if, instead of allowing a free passage to the calorific rays of the sun, it had been a ready absorber of their warmth? Then the heat which is necessary for the growth of plants would never have reached the surface of the earth, but have been swallowed up, and again radiated into space by the upper regions of the atmosphere.

The wonderful transparency of the air not only allows us to see terrestrial objects at a great distance, such as a ship rising at the brink of the horizon, or a mountain-peak raising its snow-clad summit above many miles of intervening country, but to penetrate through the whole of its crystal depths to those far-distant worlds which so magnificently bespangle the dark vault of heaven, and whose study forms one of the noblest occupations of the human mind.

As the bearer of sounds which undulate along on its elastic waves, the air likewise largely contributes to the enjoyment of life and to our intellectual improvement. Our eye might ever so much delight in the aspect of a beautiful landscape, the scene would still seem desolate and dreary if it lay before us in deep uninterrupted silence.

The waving corn-field, the rustling grove, would be bereft of

half their charms if the breeze had no power to awaken their dormant melodies. The picturesque beauty of the murmuring brook, of the bubbling source, of the river bounding over its rocky bed, or of the foaming cataract, is wonderfully enhanced by the grace or sublimity of their peculiar music, and even the ocean would be far less majestic if he had not voices harmonising with all his humours, now gently rustling over the pebbles of the sunny beach, now frantically raving against the rock-bound coast.

Thus, through our ear and through our eye, the transparent sound-bearing atmosphere holds sweet communion with our soul, and opens to its contemplation the portals of another world.

CHAPTER IV.

THE MAJESTY OF THE OCEAN.

The Immensity of the Ocean—Ebb and Flood—Causes of the Tides—Their Influence on the Organic Life of the Seas—Ocean Currents—How Produced—Their Importance—Evidences of Unity of Design resulting from the intimate Connection of the Phenomena of the Seas and the distant Celestial Bodies.

Where are the boundaries of the sea? where is its beginning or its end? It rolls through every zone, and the continents are but islands rising from its immeasurable bosom. Day and night, winter and summer, rule at one and the same time over its vast domains; the sun is ever rising and ever setting over its restless waters. Here palm-groves wave their graceful fronds over its ever-smiling margin; there eternal ice blocks up its melancholy strands; here the storm rages over the mountain-wave; there profound peace reigns over its surface, and not a breath of air ruffles its glassy brow.

Sublime in space, the sea is no less sublime in time. The present dry land bears everywhere the traces that it once rested in the bosom of the waters, and how many continents and islands may they not have swallowed in the course of unnumbered centuries, how often may they not have changed their seat and displaced their boundaries? Countless forms of animal life have one after the other appeared and perished beneath them; they have successively witnessed the birth and the death of the trilobites, of the ammonites, of the encrinites, and of the giant saurians. And how long may not the desert-ocean have rolled its waves before organic life first dawned upon it, before the first alga spread its fronds along the shore, or the first mollusk opened its valves to the tide?

What a majestic age! what a past and what a future! for the ocean, the sepulchre of so many extinct forms of animals and plants, is destined to be the grave of many others yet glowing

with all the energy of life; and when perhaps nobler beings may have taken the place of man, its waves will still sparkle in the glittering sunbeam, or thunder against the coast of some land now still reposing in its depths.

How numberless are the blessings we owe to the ocean, the father and sustainer of all organic life! He it is that feasts the stream, that fills the lake, that bubbles in the spring, that foams in the cataract, or rushes along in the mountain torrent. Should his eternal fountains be dried up, then the blooming surface of the earth would be converted into a naked waste. To him we owe the magnificence of our forests, the verdure of our meadows, the beauty of our fields. It is his waters we enjoy in the luscious fruits of our orchards, or quaff in the juice of the exhilarating grape. They circulate in the veins of numberless animals, of the bee which offers us the sweet tribute of its honey, of the bird that charms us with its melodious song, of the domestic quadruped on whose flesh we feed, and whose services are indispensable to our welfare. Nay, our own blood is originally drawn from the wells of the ocean, and is constantly refreshed and replenished from their exhaustless sources.

Far from separating from each other the nations of the earth (as the ancients, still inexperienced in navigation, supposed), the sea is the great highway of the human race, and unites all its various tribes into one common family by the beneficial bonds of commerce. Countless fleets are constantly furrowing its bosom, to enrich, by perpetual exchanges, all the countries of the globe with the products of every zone, to convey the fruits of the tropical world to the children of the chilly north, or to transport the manufactures of colder climes to the inhabitants of the equatorial regions. With the growth of commerce, civilisation also spreads athwart the wide causeway of the ocean from shore to shore; it first dawned on the borders of the sea, and its chief seats are still to be found along its confines.

The same power of attraction which governs the course of the stars, and compels the planets to wander in eternal ellipses round the sun, is also the Supreme Arbiter of the tides. How wonderful this regular undeviating alternation of ebb and flood, this immutable constancy in the midst of eternal change!—but our wonder increases when we learn that the cause of the grand phenomenon, which never fails to interest the observer, how-

ever often he may have witnessed its charming recurrence, does not reside in the bosom of the liquid element itself, but is to be sought for far away, over the remote abysses of ether, in the attractive power of the sun, and still more so of the moon, who, as she rolls along, causes the obedient waters to follow in her wake.

Thus Science teaches us: and surely no accusation was ever more unfounded than the frequent reproach that she has banished poetry from Nature, and prosaically robbed her of the enchanted garb with which she had been invested by the creative fancy of past ages, for even the brilliant imagination of a Shakespeare could not possibly have conceived a greater image than that of the ever-restless tide-wave, which, following the triumphant march of the sun and moon, began as soon as the primeval ocean was formed, and is to last uninterruptedly as long as our solar system exists!

The influence of the tides upon the marine plants and animals is of the greatest importance. A vast number of polypes, mollusks, and crustaceans thrive only within, or but a few fathoms below, the littoral zone (as the belt of rock or shingle extending from high-water to low-water mark is termed), and many of the commonest algæ best flourish when alternately bathed with floods of water and of air.

Many of these plants and lower animals could not possibly live if the continual oscillations of the tides did not constantly saturate the coast-waters with the oxygen which is necessary for their existence; and, along with these, numbers of fishes, sea-birds, and marine mammalians, such as seals, manatees, or dugongs, that now feed upon the abundance of the shallow waters, must also have been blotted from the book of life.

Thus the beautiful shells, the grotesque crustaceans, the plant-like polypes and corals which thrive best among the roaring breakers, the gulls and divers, and many other birds that dwell in the littoral zone, or hover about its skirts, are, if not all of them, yet mostly indebted for their existence to the friendly moon who sends down her rays upon them from the distance of so many thousand miles. She bears no sea on her arid volcanic surface; as far as we know, no atmospheric ocean rolls its billows over her lofty mountain-peaks; but although she herself is naked and waste, she fosters life on the shores of the ocean of another

world, and thousands upon thousands of our marine animals enjoy the light of the sun through her alone. Can chance or blind physical laws have possibly caused this wonderful dependence, or is it a divine power which has thus linked the destinies of our globe to the influence of another world?

As the atmosphere is constantly wandering from the equator to the poles, and from the regions of perpetual ice to the sultry tropics, thus also the waters of the ocean are hurried along in perpetual migrations. From the deep abysses of the seas, impenetrable to the rays of the sun, they rise to the sunny surface, or, after having revelled in the bounding wave, they again descend into the silent darkness of the submarine regions. From the coral gardens of the Pacific they are carried away to the bleak coasts where the walrus heaves his ponderous mass upon the ice, and from the desolate shores where the Esquimau harpoons the wily seal, to the delightful bay where Naples smiles upon the azure wave.

The causes which force the waters of the sea to wander thus restlessly from place to place are identically the same as those which forbid the floods of the atmospheric ocean ever to know rest; for the impulse of their migrations does not proceed from their own bosom, but from the distant sun. Absorbing the heat of his vertical beams, the expanding tropical waters are constantly rising to the surface, whence they flow onwards to the higher latitudes, where the opposite tendency takes place; for, chilled by the icy blasts of the Arctic regions and consequently increasing in weight, the surface-waters are here carried down to the bottom, and ultimately find their way to the equatorial regions.

Thus the repose of the seas is constantly disturbed by tropical heat and polar frost, but the ocean has the same tendency to restore the equilibrium of its temperature as the atmosphere, and thus those numerous warm and cold currents are produced, which, furrowing the bosom of the seas in opposite directions, are constantly exchanging the waters of the different zones.

In its lowest depths, the influence of the sun is felt; he constantly covers the bottom of the tropical seas with frigid waters and causes the warm equatorial floods to wander to the poles,—a magnificent system based upon the simple physical law of the expansion of bodies through heat and their condensation through

cold. How many thousands or even millions of cubic miles of water may not the ocean contain, but these enormous masses, too vast for the human imagination to conceive, are moved gently but irresistibly by the power of a sphere 80,000,000 miles distant from our globe!

The influence of the oceanic currents upon the organic life, not only of the seas but of the neighbouring lands, is quite incalculable. They moderate the heat of the tropical zone, and convey a considerable portion of equatorial warmth into the higher latitudes. Without the gulf-stream, whose influence may be traced as far as the west coasts of Spitzbergen and Novaja Sewlja, Scotland and Norway, where forests clothe the mountain-sides up to a height of several thousand feet, would be nothing but icy deserts; and on the other hand, the tropical west coast of South America owes its temperate climate to the cold Peruvian stream, which constantly conveys refreshing coolness from the Antarctic seas.

It may easily be conceived how this vast system of currents and counter-currents, furrowing the seas in every direction, must contribute to the dissemination of marine life. Countless spores of algæ, innumerable eggs and larvæ, are transported by the oceanic streams from place to place, and many land-animals attached to floating timber are in a like manner conveyed to distant regions.

The ocean-currents are likewise extremely favourable to marine life, from their saturating the deep waters with atmospheric air; for, as the colder superficial layers sink to the bottom, they carry along with them the oxygen they have imbibed while in contact with the air, and are thus able to impart this first necessary of life to numerous animals dwelling in the deeper waters.

As the winds purify the atmosphere, thus also the currents purify the sea by preventing the accumulation of putrefying substances and spreading them over a greater surface, where they are speedily devoured by hosts of hungry scavengers.

Besides all these beneficial influences, the marine currents tend also to equalise the saline composition of sea-water, so necessary to the welfare or existence of many of the denizens of the ocean.

Their movements also contribute to the formation of sand-

banks, where at certain seasons legions of fishes deposit their spawn, and invite the persecutions of man.

The organic life of the ocean would thus be reduced to very narrow limits, if the moon and the sun—the former by her attraction, the latter by the unequal action of his warmth upon the surface of the sea in different latitudes—did not perpetually agitate its waters; and this intimate connection between those distant celestial orbs and the sea and its inhabitants cannot but convince every reflecting mind that both derive their origin from the same creative power.

CHAPTER V.

THE ATMOSPHERICAL PRECIPITATIONS IN THEIR RELATION TO ORGANIC NATURE.

The constant Sources of the Rivers—The Harmonies of the Ocean and the Atmosphere—Distribution of Rain and Snow over the Surface of the Globe—The Voices of Rivers—Dew—History of its Formation—Clouds and Rain—Snow and Ice as Protectors of Vegetable and Animal Life—Ravines—The Glaciers—The Tornado.

THOUGH the voices of the rivers change with the varying seasons—loud and menacing in spring, when their floods are swollen by the melted snows, and softly whispering after a long summer's drought—yet, over by far the greater portion of the earth they never rest in total silence, nor does the rain ever cease to replenish their sources or to quench the thirst of the forests on the hills and of the meadows in the plains.

This uninterrupted flow of the rivers, this constant irrigation of the fields and woods, evidently points to the agency of some grand and constant law, to an admirable harmony between the wide sea below and the still more ample atmospheric ocean above.

Everywhere the air absorbs humidity, but chiefly over the surface of the tropical ocean, where, volatilised by the vertical rays of an ardent sun, the aqueous vapours ascend in amazing quantities to the skies. Thus, the equatorial seas are the principal sources which feed our brooks and fill our lakes; it is from them that the greater part of the rain arises which refreshes the verdure of our plains, and of the snow which covers the northern mountains with a white mantle of dazzling brightness.

But how are these vapours distributed over the surface of the globe? how are they conveyed to the temperate zones, or even still farther onward to the frigid poles?

The same grand system of the winds which forces the air to perpetual migrations carries also the evaporation of the ocean to distant lands. I have already mentioned in a former chapter

that cold, and consequently dry, air-currents are perpetually wandering from the poles to the equator to re-establish the equilibrium of the atmosphere, which is constantly disturbed by the mighty action of the tropical sea. The rotation of the earth gradually imparts to these cold polar streams a direction from east to west as they advance towards the lower latitudes, and ultimately changes them into the constant easterly trade winds, the mariner's delight as he crosses the tropical Atlantic on his way to the New World. As during these wanderings their temperature constantly increases, they are able to absorb a constantly increasing quantity of aqueous vapours, until they are completely saturated with moisture.

In their subsequent progress to the higher latitudes the contrary tendency takes place, for, as their temperature diminishes, they become incapable of retaining the aqueous vapours they had previously absorbed, and are thus compelled to discharge them under the various forms of rain, snow, hail, or dew, until having lost by far the greater part of their moisture, they finally reach the polar regions, whence, thoroughly desiccated, they begin again their grand circulating tour.

Thus evaporated and set in motion by the sun, the waters, ever rising and ever falling, migrate through the air. Enormous quantities of water constantly ascend from the ocean, but the countless rivers which they feed are as constantly restoring them to their source.

Though the atmospherical precipitations are very unequally distributed over the surface of the earth, as they are favoured or impeded by a variety of local causes, such as mountain-chains or forests, both of which act as powerful condensators, the prevalence of dry or moist winds, according to the geographical position, the constitution of the soil, &c., yet, on examining each land in particular, we find a remarkable uniformity in the quantity of rain that annually falls to its share. Thus, though in England some years are more moist than others, yet the difference in the annual quantity of rain only deviates a few inches from the mean average, and the deficiency of one month is generally repaired by the greater abundance of the next.

The clouds that pass over our heads pay us their regular tribute, and the authority of a higher law reigns even in the apparently free empire of the air.

It is almost superfluous to point out how necessary this constancy in the meteorological character of a country is to the well-being, or even to the existence, of its indigenous plants and animals. If after prolonged periods of continual showers, such as take place in the West Indies, equally long periods of an African drought were to follow in our country, how would then our fields and meadows be able to sustain so many millions of men and of domestic animals?

Our whole agricultural system, the whole organic life of our island, is based on the alternations of moist and dry weather which distinguish our *moderate* climate.

If the earth were everywhere covered with impermeable strata of rock, the rains would either flow off so rapidly, or be so long retained in extensive swamps and pools upon the surface, as greatly to diminish the variety and luxuriance of vegetation.

But by far the greater part of the earth-rind is composed of alternating beds or strata of impermeable clay and porous lime or sandstone, originally deposited in horizontal layers at the bottom of the primeval seas, but now more or less displaced and set on edge by the volcanic forces, which have so frequently changed the surface of the earth.

Wherever permeable beds crop out on the surface, the residuary portions of rain-water, which are not disposed of by floods or by evaporation, are absorbed into the fissures and small interstices of the porous soil, and descending into their lower depths until they reach an impermeable stratum, form the subterraneous sheets or reservoirs of water from which our springs and rivers are chiefly fed. The granite, gneiss, porphyry, lava, and other unstratified and crystalline rocks of igneous origin, which cover about one-third part of the habitable globe, are likewise intersected by innumerable fissures and interstices, which collect and transmit rain-water, and give origin to springs.

Thus the volcanic forces, which, in the course of countless centuries have moulded the earth-rind into its present form, have at the same time furnished it with the necessary filters, drains, conduits, and cisterns, for the supply of the sources, brooks, and rivers that run along its surface.

The geological convulsions of the globe, the evaporation of the ocean, the circulation of the waters over the surface of the earth, thus all harmoniously tend to the maintenance of

organic life; and truly, whoever reflects upon the manner how streams originate, and how their waters are constantly replenished, cannot fail to view them with a deeper interest than that which their mere beauty or utility inspires. To him they are not only the melodious ornaments of the valley, the highways of commerce, the benefactors of mankind, but the effects of a wonderful co-operation of physical laws, all tending to one common end, and as they rush along he fancies he hears a voice proclaiming the glories of their Maker.

Similar harmonies strike us when we examine the nature of the various atmospherical precipitations with reference to the requirements of organic life.

How beautiful is the morning dew, glittering in all the colours of the rainbow; how it refreshes the thirsty plains; how the plants raise their drooping heads under the influence of its grateful moisture! Poets have made it the emblem of purity, but physical science, by revealing to us the simple laws that preside over its formation, has rendered it more beautiful still to the reflecting observer.

Everybody knows that, when in summer a bottle filled with cold water is brought into a warm room, it soon gets covered with thick dew-drops, which presently trickle down its sides, although it was perfectly dry on entering. Whence does this moisture proceed? Not from the inside of the bottle, as ignorant people might imagine, but from the surrounding atmosphere, in consequence of the capacity of the air to absorb or retain moisture, increasing or diminishing as its temperature grows warmer or colder.

Thus, when the cold bottle is introduced into the room, the warm sheet of air, which is in immediate contact with its surface, immediately cools, and being no longer able to retain the same quantity of aqueous vapours, is obliged to deposit them on the sides of the vessel. As it cools, its weight also increases, it flows downwards, warmer air takes its place to cool in its turn, and thus there is a perpetual deposition of moisture, until the temperature of the bottle has risen to that of the surrounding atmosphere.

This familiar example suffices to explain the formation of dew, and of all other atmospherical precipitations, such as rain, hail, or snow, as they all result from the influence of

some refrigerating cause upon the air. After sunset, most bodies, by projecting or radiating heat into free space, become colder than the neighbouring air, and as soon as their refrigeration has attained a certain point, they must naturally, in consequence of the physical law above mentioned, get covered with dew. The best radiators of heat part, of course, most easily with their caloric, and for this reason grass, leaves, or plants in general, get much sooner and more plentifully covered with dew than slower radiators, such as stones, the soil, or metals, which frequently still remain dry when the meadows are already covered with plentiful moisture. Hence we can understand why, in summer, every serene night (for clouds, by reflecting or throwing back again upon the terrestrial surface the caloric which would else have been dissipated into space, prevent its rapid refrigeration) is accompanied with a copious formation of dew; why it is more abundant in autumn and spring than at any other season, as then very cold and starlight nights frequently follow upon warm days, and why it is most copious in the torrid zone, as in those sultry regions the air is more saturated with moisture than anywhere else, and the comparatively cold nights are almost constantly serene and calm.

Had naked stones been as good radiators of heat as leaves or herbs, then the latter would vainly have thirsted for refreshment, while the former would have been bathed in useless moisture.

Had the dew been plentiful during violent winds, the plants must frequently have suffered, or been frozen to death in consequence of the rapid evaporation of their moisture.

Where the sun has most power, where during the day he most thoroughly dries up the soil, there also the cool night is most prodigal of dew.

Thus the history of dew gives us many opportunities of admiring the wisdom that has presided over its formation and distribution.

While dew is merely produced on the surface of solid bodies, the refrigeration of large volumes of air forms clouds or fogs, consisting of vast numbers of minute globules, or vesicles of moisture, which float like soap-bubbles in the atmosphere, until, their quantity increasing with the cold, or in consequence

of electrical discharges, they unite to larger drops, and fall to the ground under the various forms of rain, snow, or hail.

The rain-drops grow as they fall from a greater height, and traverse the warmer and more humid atmospherical strata, which are generally nearer to the surface of the ground. It is a well-known fact that there is a considerable difference in the quantity of rain falling within the same time upon the summit of a hill, or at its foot, and thus the elevated clouds, from which the rain originally descends, are merely its starting-points.

This gradually increasing weight of the rain-drops as they fall is of great importance to vegetation. Had they at once attained their full size at a considerable height, they would have descended with terrific violence, and every shower of rain must have been equal to a hail-storm in its destructive effects. So much ground would also have been washed away from the hill-slopes by these pelting floods, that large tracts of fertile country must have been converted into naked wastes.

In the tropical zone the rain indeed frequently falls in such dense torrents as to produce a painful impression on the skin; but here the structure of the plants harmonises with the meteorological character of the climate. Genera with thick compact leathery leaves, which even the strongest rain cannot damage, are prevalent; and such plants as have a more delicate foliage mostly grow under the protecting canopy of the forest. The grasses and cereals, such as maize and the sugar-cane, are of a more robust growth than our indigenous species, and the fruits generally ripen after the rainy season is past, or grow under the shelter of a dense crown of leaves.

The congelation of water at the comparatively moderate temperature of $+32°$ F., when it either drops as snow from the atmosphere, or covers the brooks and rivers with a sheet of ice, is of immense importance to vegetation in the higher latitudes; for snow is so bad a conductor of heat, that under its protecting mantle the plants of the Arctic regions are able to resist the utmost rigours of the cold. Buried eight or ten feet deep under its crystal pall, they pass the long winter in a temperature not much below freezing point, while without icy blasts—capable of converting mercury into a solid body—howl over the naked wilderness. But for this protection,

no flowers would ever bloom in Spitzbergen or Nowaja Semlya, where now many a ranunculus or purple silene

> 'is born to blush unseen,
> And waste its sweetness on the desert air

but for this, no trace of verdure could ever enliven the desolate shore of Melville Island, or fringe the estuaries of the Mackenzie.

Many of the Arctic animals that have not been gifted with the capacity, or the instinct, to undertake long journeys in quest of a milder climate, likewise owe the preservation of their life to the thick non-conducting snow-mantle under which they lie concealed during the long winter months. Without this covering they would freeze in their burrows, or the iron soil would refuse them the nourishment which they find by digging or scratching in its entrails.

What would become of the migratory birds, which, at the beginning of summer, arrive in countless swarms on the banks of the northern waters, if the snow had not harboured an infinite number of worms under its warm cover? And what would be the fate of the rude inhabitants of the Arctic world, who, after the long penury of winter, anxiously are awaiting their arrival, if their winged legions were to omit their visits?

So much is certain, that if during the Arctic winter only cold showers of rain fell upon the earth, or if the frozen aqueous vapours of the atmosphere, instead of descending in light flakes of snow, were to pour down in thick hailstones, vast tracts of country now blooming with a rich summer vegetation, and capable of affording nourishment to numerous animals, would have been nothing but naked wastes.

The loose movable nature of snow greatly facilitates its removal from the highlands of the earth. Scarcely have the warm breezes of spring fanned the mountain vales of Switzerland, when numberless small lavines are seen to descend from every declivity like streamlets of floating silver. Their loud voices sound like delightful music to the herdsman, who greets them as the heralds of approaching abundance. For wherever they leave the slope uncovered, the sun and rain act with a double force, and thus in a short time vast quantities of snow, which would have given way but slowly to the unassisted efforts

of the sun, disappear from the hills, and soon make room for a rich carpet of verdure.

Thus the lavines are of incalculable advantage to the Alpine mountaineer, who now drives his herds on many a pasture-ground which, but for them, would be condemned to perpetual sterility.

It might be supposed that the snow, filling the deep gullies or basins of the higher Alps, and thence pouring in streams of solid ice into the valleys, must be eternally fixed on earth, and that their imprisoned waters could never find their way back again to the ocean. The glaciers of the Mont Blanc or of the Bernese Oberland seem perennially to defy the warmth of summer; but their immobility is merely apparent, for the pres*sure of the superincumbent masses is so great as to force them* perpetually downwards as if they were a viscous body, until at length the consumption below equals the supply above.

Thus slowly, indeed—for the velocity of the great glaciers of the Alps rarely exceeds two feet a day—but yet not less surely than if they bounded in foaming catâracts down the valleys, or rolled in rapid currents through the plains, the consolidated waters above the snow-line are ultimately restored to their parent seas.

In the same manner Greenland, Spitzbergen and many other mountainous countries of the Arctic zone, divest themselves of the snows which cover their dreary wastes, and thus an accumulation is prevented which might have been dangerous to the whole economy of organic nature.

The property of water to expand and thus to become lighter on assuming the solid form of ice, is of the greatest importance to the maintenance of organic life over a great portion of the globe.

If ice were heavier than water, the beds of the rivulets and rivers, of the ponds and lakes, in the higher latitudes would be covered with a sheet of congealed water as soon as the first frosts of winter appeared, and in a very few days the mightiest streams would be converted, throughout their whole depth, into one solid mass, which even a long summer would hardly have been able to thaw, or which in many cases would have triumphed over all its efforts. But ice remaining on the surface, and being, like snow, a bad conductor of heat, increases but slowly in thickness as the rigours of winter increase, and thus, even in Siberia, the

rivers are only frozen to a depth of eight or ten feet. As soon as the first warm days of spring appear, the thawed surface-waters gather under the ice-cover, raise it with irresistible force, and, bursting the bonds with which it enthralled the current, bear its fragments along to the river's mouth, where they are soon dispersed over the ocean.

In a short time all is life and activity in the liberated waters. Millions upon millions of worms, mollusks, insects, and reptiles awaken from their winter lethargy, the sweet-water fishes emerge from the mud in which they lay plunged in torpor, and from the sea other legions come pouring in to trust their eggs to the warmer stream. All this would not have been possible, all this activity and enjoyment could never have existed, if the weight of ice had been superior to that of water.

Then also the Arctic and Antarctic seas would have been converted into solid masses, which the sun would have been as incapable to melt as he is unable completely to liquefy the glaciers of the Alps. In consequence of the cold radiating from their surface, these vast oceans of ice would have encroached upon a great part of the temperate zones, and, by preventing that beneficial system of maritime currents through which a considerable portion of tropical heat is transported into the higher latitudes, would have still further contributed to extend the domains of perpetual winter. And, finally, the exhalations of the tropical ocean which now regularly return to its bosom, would have accumulated in such vast masses in the colder regions, that in all probability the fountains of the sea would have been finally exhausted of the greater part of their waters, and the dry land converted into an arid waste. So much is certain, that at best but a small portion of the globe would have been a fit habitation for man, who, thus confined to a narrow space and plunged in barbarism, could never have fulfilled the higher objects of his existence.

Thus the physical laws on which the circulation and the migrations of the waters over the surface of the globe depend, have all been made to harmonise with the wants of animal life, or the higher requirements of the human race; thus they all contribute to extend the domains of organic nature.

The meteorological phenomena are but exceptionally or locally destructive; their general effect is constantly beneficial. Vast

tracts of country are perpetually fertilised by refreshing showers or copious dews; the snow covers whole zones with his protecting mantle, while the pelting hail-storm generally devastates only narrow districts. The winds are universal ventilators: health and plenty sail along upon their invisible wings, and fleets are unceasingly wafted by their breath from shore to shore; but the dreadful tornado is but a rare atmospherical crisis, and even the ravages it causes are not unmixed with good, for many a pestilential disease has been arrested by its appearance, and many an insect plague has been swept away by its drenching torrents. The greater violence of the tropical storms is counterbalanced by a more vigorous vegetation, which effaces their traces in a shorter time.

Thus everywhere the bounty of the Creator mitigates the evils resulting from the perturbation of the regular course of nature; thus everywhere His apparent anger is but the means of conferring new blessings upon His creatures.

CHAPTER VI.

THE HARMONIES BETWEEN THE PHYSICAL CONSTITUTION OF THE EARTH AND ITS INHABITANTS.

The Terrestrial Revolutions—The Formation of Alluvial Plains—Beneficial Effects of the Inequalities of the Earth's Surface—What do Petrifactions teach?—Coal-strata—The Subterranean Treasuries of Man—Influence of the Change of Seasons on Organic Life.

THE sun, the planets, or even our satellite the moon, are so far removed from our sphere that we can never hope to acquire an accurate knowledge of their structure; but the earth, our parent and our inheritance, lies open to our view. We traverse it in all its zones, we measure the depth of its waters, we probe its superficial strata, we examine the petrified remains of extinct plants and animals which it harbours in its bosom as in a vast sarcophagus of the past; we study its annals in the deposits of the primeval ocean, in the effects of *its subterranean fires, in its volcanic eruptions, in the heavings and subsidences of its* surface; and thus many of the secrets of its history have been revealed to us, and the eye of science is able to penetrate far back into the times that have preceded the present configuration of its continents and seas.

Thus we know that since immemorial ages water and fire, these two hostile elements, have been constantly engaged in modelling and remodelling its surface; each striving for the mastery, each eager to destroy the formations of its opponent.

The subterranean fires have never ceased to react against the solid earth-rind which confines them in iron bondage, to pile up mountain-chains above the fissures caused by their expanding force, to heave up continents from the bottom of the seas, to pour forth torrents of liquid stone from the bosom of the volcano, or to shake whole continents, like a lion impatiently

bounding against the gratings of his dungeon. But the waters, in alliance with the disintegrating influences of the atmosphere, have been as constantly active in destroying the igneous formations, in splitting and dissolving the mountain-peaks, in reducing crumbled rocks into smaller and smaller fragments, and in washing them down to a lower level, destined to be again and again upheaved, and then again and again swept into the ocean.

Thus the actual state of the earth-rind is the result of innumerable elementary conflicts, whose records, written in pages of stone and petrified remains, enable the geologist to reconstruct the magnificent epic of its history, as the learned decipherer of the hieroglyphics and cuneiform inscriptions of Egypt and Persepolis is able to exhume from the tomb of past ages the traces of an extinct civilisation.

Scarcely any branch of natural history is more interesting than that which treats of the formation of our earth-rind; but undoubtedly the most important question which geology is called upon to solve is, whether the conflicting powers of fire, water, and air have evermore been acting and reacting upon each other in blind confusion, building and destroying in chaotic and fortuitous anarchy, or whether, from the first moment that their strife began, their movements have constantly been directed by a higher hand, and rendered subservient to the establishment and progressive development of organic life?

The answer cannot for an instant be doubtful. Every chapter, every page of the annals of our globe, affords us the most convincing proofs that the elementary forces have ever been the docile instruments of a superior Power; that, long before organic life appeared on earth, fire and water were busy preparing for its future residence.

On the hard impenetrable rock nothing grows but a lowly race of lichens and mosses, while all plants of a higher order absolutely require a loose soil for the insertion of their roots and the supply of an adequate amount of nourishment.

On examining the structure of the earth, we find how much the high mountain-chains have contributed to the formation of considerable tracts of fertile land. On their naked brows the disintegrating power of winter acts with the greatest energy. There also the clouds chiefly concentrate their vapours, there they condense most frequently into snow or rain, and there the

flowing waters carry the spoils of winter most violently along in their precipitous course. Thus, in those elevated regions, new surfaces of solid rock are constantly exposed to the corroding atmosphere, and thus the first alluvial plains on which a more luxuriant vegetation could arise, were formed at the foot of the mountains out of the wrecks and ruins of their peaks.

According to a universal hydrostatic law, the velocity at the bottom of a stream is everywhere less than in any part above it, and is greatest at the surface. The superficial particles in the middle of the stream also move more swiftly than those at the sides. This retardation of the lowest and lateral currents is produced by friction, and when the velocity is sufficiently great, the soil composing the sides and bottom gives way. A velocity of three inches per second at the bottom is ascertained to be sufficient to tear up fine clay; six inches per second fine sand; twelve inches per second fine gravel; and three feet per second stones of the size of an egg.

We can thus easily understand how mountain-torrents descending with great velocity are able to sweep along vast quantities of gravel, sand, and mud; but a question naturally arises, how the more tranquil rivers of the valleys and plains, flowing on comparatively level ground, can remove the prodigious burden which is discharged into them by their numerous tributaries, and by what means they are enabled to convey the whole mass to the sea? If they had not this removing power their channels would be annually choked up, and the valleys of the lower country and the plains at the base of mountain-chains would be continually strewed over with fragments of rock and sterile sand. But this evil is prevented by a general law regulating the conduct of running water—that two equal streams do not, when united, occupy a bed of double surface. In other words, when several rivers unite into one, the superficial area of the fluid mass is far less than the areas previously occupied by the separate streams. The collective waters, instead of spreading themselves out over a larger horizontal space, contract themselves into a column of which the height is greater relatively to its breadth. Hence, a smaller proportion of the whole is retarded by friction against the bottom and sides of the channel; and in this manner the main current is often accelerated in the lower country, even when the

slope of the river's bed is lessened. It not unfrequently happens, that two large rivers after their junction have only the surface which one of them had previously; and even in some cases their united waters are confined in a narrower bed than each of them filled before. By this beautiful adjustment, the water which drains the interior country is made continually to occupy less room as it approaches the sea, and thus the most valuable part of our continents—the rich deltas and great alluvial plains—are prevented from being constantly under water.*

The inequalities of the earth's surface, the elevation of vast tracts of country many thousand feet above the level of the sea, and the deep valleys which the torrents have gradually scooped out in the flanks of the mountains, are also prominent causes of that wonderful variety of climate which gives birth to a no less wonderful variety of plants and animals.

Fancy the mountains brought down to the level of a uniform plane; no peaks soaring aloft into the regions of perpetual snow, no declivities leading the wanderer in a few hours from Arctic coldness to the genial mildness of an Italian sky; no precipitous streams, whose foaming waters as they bound along first reflect the dark pine in their crystal mirror, then the sturdy oak, and finally the noble chestnut or the graceful laurel; and then how monotonous would be the landscape, how uniform the character of organic life over vast tracts of country where now vegetation, thanks to the perpetual changes of elevation and aspect of the soil on which it grows, is seen revelling in an endless multiplicity of forms.

The actual distribution of sea and land over the surface of the globe is likewise of the highest importance to the present condition of organic life. If the ocean were considerably smaller, or if Asia and America were concentrated within the tropics, the tides, the oceanic currents, and the meteorological phenomena on which the existence of the vegetable and animal kingdoms depend, would be so profoundly modified, that it is extremely doubtful whether man could have existed, and absolutely certain that he could never have risen to a high degree of civilisation.

The dependence of human progress upon the existing configu-

* Sir Charles Lyell's *Principles of Geology.*

ration of the globe necessarily leads us to the conclusion that both must be the harmonious work of the same Almighty Power, and that a divine and immutable plan has from all eternity presided over the destinies of our planet. It is almost superfluous to point out how largely the irregular windings and indentations of the coasts, the numerous islands scattered over the face of the waters, the promontories stretching far away into the domains of the sea, and the gulfs plunging deeply into the boson of the land, have contributed to the civilisation of the human race by multiplying its points of contact with the ocean, the great highway of nations.

A survey of the petrifactions enclosed in the various strata of the earth adds new force to the conviction, that one grand and uniform plan has constantly presided over all the periods of its history. For here we find no chaotic confusion, no arbitrary oscillations from higher to lower, or from lower to higher grades of existence (as would undoubtedly have been the case if organic development had been left to casual influences), but a gradual and constant progression from inferior to more perfect forms of life.

Thus, in the oldest strata only the remains of the lower plants and animals are found—of algæ and lichens, of corals, sea-urchins, mollusks, and crustaceans.

At a later period the reign of the vertebrated animals begins to dawn in the fishes. Then the reptiles appear in gigantic forms, as tyrants of the coasts and the lagunes, while the empire of the birds and quadrupeds belongs to the more recent formations; and man, the most highly gifted of all the created beings we know of, appears last upon the scene.

Throughout these vast epochs of time, numberless species of vegetable and animal life are doomed to perish, but they are constantly replaced by other and more perfect forms; we see constant changes, a constant decline and death, but also a constant birth and resurrection, a new life perpetually springing forth from the ruins of the past. How perfect must have been the plan which has thus, through unnumbered ages, constantly maintained the balance between the changes and revolutions of the earth-rind, and the eternal progress of the organic world!

The elementary powers of fire and water might have continued their strife for ever, and yet the higher grades of animal life

could not have been called into existence if vegetable life, favoured by peculiar atmospherical conditions, had not previously cleansed the air of the pernicious gases with which it was saturated during the early period of our earth's history.

The ocean then rolled its waves over a far greater surface than at present, for the large masses of land which now cover a considerable part of the northern hemisphere were then still reposing under the waters, which only appeared speckled here and there with low and comparatively insignificant islands. Thus a mild oceanic climate reigned far to the north, and its moist and genial breath decked with a verdant robe even Spitzbergen and Bear Island, where now winter with all his horrors holds undisputed sway over the ice-bound soil.

Besides moisture and warmth, the immense quantities of carbonic acid which was at that time mixed with the atmosphere, contributed to promote vegetation; for this gas, so deleterious to man and to the higher animals, constitutes, as is well known, the chief food of plants, which have the power of separating it into its constituent elements—oxygen and carbon, restoring the former to the air, and forming out of the latter the greater part of their solid structure.

The immensity of the coal-fields affords convincing proof of the abundance of carbonic acid which filled the air at that primeval epoch, for before its carbon became condensed by vegetation, it evidently must have existed in a gaseous state; and thus also we see that the forests of this carboniferous period first paved the way for a higher development of animal life, by purifying the air and substituting oxygen for the deleterious vapours with which it was loaded.

Although the vegetable remains which constitute coal are mostly in such a state of compression or transformation that no trace of the original texture remains, yet the specimens which one is able to distinguish from the mass plainly bear the character of a swampy vegetation, and show that they must have grown in submerged or at least extremely humid situations, analogous to those in which the present peat or turf formation takes place.

These relics of an extinct world chiefly consist of cryptogamous or non-flowering plants, such as arborescent ferns, and reed-like calamites, stigmarias and lepidodendra, along with a few palms

and first; but the beautiful and various forms of the dicotyledonous plants, which constitute by far the greater part of the Flora of the present day, were totally wanting in the swampy forests of the carboniferous period, which, in spite of their amazing luxuriance of growth, had but a monotonous and melancholy character. No warm-blooded quadruped enjoyed their shade, no bird enlivened them with his song. Their awful silence was only interrupted by the tones of inanimate nature, the roaring of the sea against the low beach, or the moaning of the wind in their feathery fronds. But who knows whether spirits hovering over their dreary expanse may not have whispered to each other of the nobler creation for which they paved the way!

The great uniformity of climate which then reigned over the globe caused at the same time a wonderful uniformity of vegetation in its various zones. In the eastern as in the western hemisphere, between the tropics and beyond the Arctic circle, wherever coal has been deposited the naturalist meets with the same forms, often even with the same species of plant.

The space of time required for the formation of the coal-fields is as immeasurable as the countless millions of miles that separate us from Sirius.

We know by experience how thin the sheet of humus is which the annual leaf-fall of our forests or turf-plants produces, and how many decenniums must pass ere one single inch of solid residuum is gained. But there are many coal-strata twenty to thirty feet thick; and if we consider besides the mighty pressure of the superincumbent rocks which store them in the smallest compass, we cannot possibly doubt that *one* such stratum must have required thousands of years for its formation. Our wonder increases when we reflect that, in many carboniferous basins no less than a hundred thick and thin seams of coal alternate with layers of sandstone and shale, so that the reckoning would swell to millions, were we able to fathom the ages of their successive growth.

Thus, for instance, at Sheriff Hill, near Newcastle, we find eight strata of coal of a joint thickness of thirty-three feet and a half, but these are separated by intervening stone strata of an average thickness of from forty to sixty feet, so that the entire thickness of these coal measures amounts to 345 feet.

But even these coal-bearing strata form but a small part of

the whole carboniferous system, whose successive stages (lower carboniferous shale, carboniferous limestone, millstone grit, coal-measures, upper coal grits, lower new red sandstone) frequently measure no less than from 6,000 to 8,000 feet in thickness; or even as in South Wales, Nova Scotia, and near Saarbruck, 13,000, 14,000, and 20,000 feet! The wings of fancy fail to carry us over the vast chasm which separates the first of these deposits from the last; and yet the whole system itself is but a link in the chain of successive formations of which the earth-rind, as far as we are able to sound its depth, is composed.

Truly man is but the creature of a day, and yet it is for him that the primeval forests grew, that the mighty ferns waved their fronds in the desert air, and that the marshy plants spread their succulent leaves and stems, unnumbered ages before he was to appear upon the scene.

The alternating strata of coal and stone of which the carboniferous system consists, can hardly be explained in any other manner than by a *general* slow subsidence of those coasts on which the vegetation flourished, alternating with periods of rest.

During an epoch of subsidence, the humus-layer formed by the deposits of ages of forest growth was inundated, and gradually became covered with a system of sand or mud, upon which in the following period of repose a new swampy vegetation could arise and continue to flourish until a new subsidence once more whelmed it beneath the waters. Thus gradually coal followed upon sand, or sand upon coal, until the whole mighty series was built up!

Although all coal-fields must have originally been formed in horizontal or slightly undulating situations, yet in many cases they have undergone enormous derangements from the subsequent action of volcanic powers. Thus, in the Belgian carboniferous formation, the strata are not only violently contorted, but often elevated through an angle greater than a right angle, and are thus actually inverted, so that the basin-shaped depressions in which the coal occurs are twisted out of place, and the whole geology of the district apparently thrown into confusion.

Faults are in fact so common in coal-strata, that they are but rarely missing. They occur in every possible dimension, so that sometimes the severed parts of a field have been displaced many hundred feet from their original position.

One can easily conceive the difficulties which these disruptions frequently throw into the miner's way, who, in following what he considers a valuable seam of coal, is suddenly stopped by coming in contact with a fault, and finds the coal shifted several yards above or below, or even completely lost.

On the other hand they are productive of considerable advantages, for by intersecting a large field of coal in all directions, and by the clayey contents which fill up the crack accompanying the fault, they become *coffer-dams*, which prevent the body of water accumulated in one part of the field from flowing into any opening which might be made in it from another. This separation of the coal-field into small areas is also important in case of fire, for in this case the combustion is prevented from spreading widely, and destroying, as it would otherwise do, the whole of the seam ignited.

'The natural disposition of coal in detached portions,' says the author of an excellent article in the 'Edinburgh Review,'* 'is not simply a phenomenon of geology, but it also bears upon national considerations. It is remarkable that this natural disposition is that which renders the fuel most accessible and most easily mined. Were the coal situated at its normal geological depth, that is, supposing the strata to be all horizontal and undisturbed or upheaved, it would be far below human reach. Were it deposited continuously in one even superficial layer, it would have been too readily, and therefore too quickly, mined, and all the superior qualities would be wrought out and only the inferior left; but as it now lies it is broken up by geological disturbances into separate portions, each defined and limited in area, each sufficiently accessible to bring it within man's reach and labour, each manageable by mechanical arrangements, and each capable of gradual excavation without being subject to sudden exhaustion. Selfish plundering is partly prevented by natural barriers, and we are warned against reckless waste by the comparative thinness of coal-seams, as well as by the ever augmenting difficulty of working them at increased depths. By the separation of seams one from another, and by varied intervals of waste sandstones and shales, such a measured rate of mining is necessitated as precludes us from entirely robbing posterity of the most valuable mineral fuel, while the fuel itself is

* Vol. cxi. p. 80.

preserved from those extended fractures and crumblings and falls, which would certainly be the consequence of largely mining the best bituminous coal, were it aggregated into one vast mass. In fact, by an evident exercise of forethought and benevolence in the Great Author of all our blessings, our invaluable fuel has been stored up for us in deposits the most compendious, the most accessible, yet the least exhaustible, and has been locally distributed into the most convenient situations. Our coal-fields are so many *Bituminous Banks*, in which there is abundance for an adequate currency, but against any sudden run upon them nature has interposed numerous checks; whole reserves of the precious fuel are always locked up in the bank-cellar under the invincible protection of ponderous stone-beds. It is a striking fact, that in this nineteenth century, after so long an inhabitation of the earth by man, if we take the quantities in the broad view of the whole known coal-fields, so little coal has been excavated, and that there remains an abundance for a very remote posterity, even though our own best coal-fields may be then worked out.'

But it is not only in these inexhaustible supplies of mineral fuel that we find proofs of divine foresight, all the other treasures of the earth-rind equally convince us of the intimate harmony between its structure and the wants of man. Composed of a wonderful variety of earths and ores, it contains in inexhaustible abundance all the substances he requires for the attainment of a higher grade of civilisation. It is for his use that iron, copper, lead, silver, tin, marble, gypsum, sulphur, rock-salt, and a variety of other minerals and metals, have been deposited in the veins and crevices, or in the mines and quarries, of the subterranean world. It is for his benefit that, from the decomposition of the solid rocks results that mixture of earths and alkalies, of marl, lime, sand, or chalk, which is most favourable to agriculture.

It is for him, finally, that, filtering through the entrails of the earth, and dissolving salutary substances on their way, the thermal springs gush forth laden with blessings and enriched with treasures more inestimable than those the miner toils for.

Supposing man had never been destined to live, we well may ask why all those gifts of nature—useless to all living beings but to him—why those vast coal-fields, those beds of iron ore, those

deposits of sulphur, those hygeian fountains, should ever have been created? *Without* him there is no design, no purpose, in their existence; *with* him they are wonderful sources of health or necessary instruments of civilisation and improvement. Thus the geological revolutions of the earth-rind harmoniously point to man as to its future lord; thus, in the life of our planet and that of its inhabitants, we everywhere find proofs of a gigantic unity of plan, embracing unnumbered ages in its development and progress.

The obliquity of the earth's axis to the plane of its orbit, through which in its annual course round the sun each pole is alternately presented to the rays of the great luminary, is likewise of such vast importance to organic life, that it must have been from the beginning established with a view to the place we were one day to occupy on earth.

Supposing the equator of our globe to have been invariably exposed to the vertical sunbeams, then all the year round short March or September days would have fallen to the share of the temperate zones, and both the poles would have been plunged in constant darkness. The higher latitudes, covered with perpetual ice, must have been totally uninhabitable, and the numerous plants which require the summer's heat for the ripening of their fruits must have been banished from our fields.

The perpetual cold of the poles would no doubt have extended the domains of ice and snow far beyond their present boundaries, and man would have been restricted to a torrid belt, whose narrow confines would have condemned him for ever to a mere animal existence.

And now compare reality with this imaginary picture, and see how beautifully, by the wanderings of the sun from one tropic to the other in his apparent annual motion, his genial warmth is widely distributed over the earth; how the various seasons—spring with his blossoms, summer with his nourishing corn, autumn with his abundance of fruit, and winter with his cheerful hearth—are made to follow each other in charming succession, and to enrich the intellectual life of man by constantly opening new scenes and prospects to his view. It was only thus that he could become master of the earth and of its treasures, and that organic life could develope itself in countless forms up to the icy poles.

external forms, but also in the duration of their existence, and in the aggregation of their parts. While centuries have elapsed since the giant Wellingtonias first germed on the mountain-slopes of California, a single summer's night bounds the fleeting life of the mushroom; and while the slightest touch suffices to bruise the delicate ulvæ of our ponds, ebony blunts the sharpness of the woodman's axe.

And how infinite the transitions between all these extremes; how gradually through thousands of species one form or colour passes into another; how imperceptibly softness changes into hardness, or the life of a day expands into an existence of centuries. Surely we require no other proof that the whole world of plants is but the infinite modification of one and the same Divine idea thus made to agree with equally infinite variations of climate and soil; but even the last doubts as to the fundamental unity of the countless members of the vegetable kingdom must disappear when we come to examine their internal structure.

For, armed with the microscope, botanists have discovered that every vegetable fabric consists simply of an aggregation of *cells* or closed membranous bags or vesicles, and their unwearied observations have been able to trace the gradual change of this simple elementary form into every variety of tissue, fibre, and vessel, which enters into the organisation of the most complicated plants.

The permeable cell-wall absorbs the nutritious fluids with which it comes into contact, and these, by the chemical processes which are constantly going on in its interior, are changed into new substances, which the cell partly appropriates to its own uses and partly excretes, so as to be able to absorb fresh fluids in their place. The constant succession of these simple physical and chemical actions forms the whole life-history of the individual cell—and consequently of every plant, which, however complicated its structure may appear, is after all but an aggregation of cells.

During the progress of growth the primordial form of the originally globular cell assumes a great diversity of shape; it extends in length, it branches out, it is flattened by the pressure of its neighbours, or compressed into a many-sided or prismatic figure.

Throughout all these changes the cell-wall may retain its original thinness and transparency, but very frequently it becomes thickened and opaque by the successive deposition of layers of solid matter, while at the same time its fluid contents disappear and its individual growth is at an end. The thickening is generally not uniform over its whole surface, but presents frequent interruptions, so that the cell appears punctured with numerous round pores, or creviced, or covered with a network, or with a spirally wound-up band, or with a succession of opaque rings; and from all these modifications of solidification and growth result the endless varieties of texture which we admire in the vegetable kingdom, and which must appear the more astonishing when we consider the simple elementary form from which they all derive their origin.

In most cases the growing cells multiply by duplicate subdivision, each half increasing in length, and again dividing through a transverse partition, or else new cells form in the interior of a parent cell and expanding burst open the shell or case in which they were contained. Thus the growth of all plants proceeds by a constant multiplication of cells whose number frequently increases to an incredible extent as a cubic inch of soft cellular parenchyma contains more than 100,000,000 individual cells. The simplest plants, the confervæ, algæ, lichens and mushrooms, consist only of soft cellular tissues, and in these, owing to their loose nature, growth frequently proceeds with a most marvellous celerity. In twenty-five minutes a mushroom—the Phallus fœtidus—shoots up three inches high, and in another species—the *Bovista gigantea*—20,000 new cells form every minute, so that in a single night it swells from the size of a pin's head to that of a large pumpkin. Thus also the Nereocystis lutkeana, an alga occurring on the north-west coast of America, which has stems resembling whipcord, three hundred feet in length and terminating with a bunch of leaves each thirty or forty feet long, is but the produce of a single summer, so that it is hardly an exaggeration to say that one might see it grow. A proper seed formation does not take place in these inferior plants, they generally multiply by the emission of spores—simple cells—which are often generated in truly incalculable numbers. More than 10,000,000 of spores have been found in a single specimen of Reticularia maxima, a mushroom growing on

the trunks of felled trees—each of them most likely able to produce a new individual; and as every species of mushroom or fungus is equally productive according to its size, we can easily understand how these microscopical germs frequently float in the air in countless myriads, until the casualties of wind and weather again precipitate them upon the earth.

The well-known instances of the dry rot in timber, or of the potato and grape diseases, sufficiently prove how disastrous the enormous reproductive powers of the fungi may become when circumstances favour their growth; but in many cases they are extremely useful, by promoting the decomposition of decaying or putrefying vegetable and animal substances, and thus hastening their transition into new forms of life.

The structure of the higher order of plants, such as have flowers and seeds, is far more complicated than that of these simple forms of vegetation, as they consist not merely of a more or less closely aggregated or firmly woven cellular tissue, but also of fibres and vessels that have grown out of that elementary form, and minister to the wants of a more complicated organisation.

One of the most wonderful properties of the vegetable cell is its power of elaborating such an amazing variety of products. It receives or imbibes but few substances from the outer world, water, carbonic acid, ammonia, and some other soluble salts; but with these few it is able to bring forth in its secret laboratory all that can gratify the eye, the smell, or the taste of man.

The beautifully tinted juices to which the flowers owe their rainbow variety of colours, the sweet odours with which they perfume the air, the gums, the balsams, and the resins, sugar and starch, india-rubber and gutta-percha, medicines and poisons in endless profusion, are all distilled or fabricated by the vegetable cell.

Even the humblest lichen, the smallest moss which clothes the weatherbeaten rock, is a truly miraculous production; how then can we find words to express our admiration of those thousands upon thousands of flowering herbs, shrubs, and trees, whose endless and picturesque variety inspires every feeling heart with delight and gratitude?

While the northern bard praises the stately magnificence of the oak, the Arabian minstrel sings the date-palm's stately

crown; and the poets of all lands and of all times never tune their harps to sweeter melodies than when describing in rapturous strains the balmy groves or the verdant meads of the beloved country of their birth.

It is no caprice of chance or blind agency of mechanical or physical laws which has so wonderfully decorated the earth, and gifted us with such a deep-felt sympathy with the charms of the vegetable world.

When Nature revives in spring, and thousands of birds make the woods and fields resound with their song, then also a voice awakens in our heart which tells us that all these lovely scenes are but the visible revelation of an invisible God, an enchanted mirror in which we see the reflection of His glory.

CHAPTER VIII.

THE ROOTS OF PLANTS.

The Roots of the Algæ, of the Zostera marina, of the Sand-reed, of the South African Creepers—The Roots of the Forest Trees—Aërial Roots of the Mangroves—Their Influence on the Formation of Tropical Deltalands—Radical Filaments—Spongioles—Properties of Vegetable Mould—The Fertilising Influence of Winter.

EXPOSED to the influences of every climate and destined to grow in every soil, children of the sea, the dry land, and the air, the plants needed a wonderful pliability of organisation to be able to adapt themselves to the numberless modifications of the external world, resulting from their universal distribution over the surface of the globe.

As each animal is armed at all points against hostile attacks, or provided with all the organs it requires for waging the battle of life, thus also every plant, wherever it may grow, has been endowed with the means of maintaining its existence against a host of adverse influences; and each of its parts and organs—its roots, its stem, its leaves, its flowers, its fruit—is in every case a masterpiece of adaptation to the circumstances under which it is destined to flourish.

Thus also the study of each vegetable organ gives the philosophical observer equal opportunities of admiring the profound wisdom which presided over its formation, and in his eyes the perfection of nature reveals itself as eloquently in the homely root as in the gayest blossom expanding its gorgeous colours to the sun.

See the vile seaweed, exposed to all the vicissitudes of the tides; *fixed on a solid rock, it is unable to plunge its roots into* the stone to which it adheres; and yet they are such excellent holdfasts, that even a violent storm is hardly able to sever the connection, and cast the plant ashore like a ship torn from its

anchors. Frequently a simple conical disc suffices to bind the weatherbeaten alga to its native cliff; and as the hardy plant advances in growth, and as new props are required to support the additional weight, the branches of the root lengthen, and others are gradually added, till a compact mass of interwoven fibres is formed, each of which takes a separate gripe of the rock by the disc at its extremity, so that their united powers of resistance are able to bid defiance to the swelling flood.

The Laminariæ, or Oar-weeds of our coasts, with their long broad leaves cloven into a great number of ribbon-like segments, sufficiently prove the strength of an adherence which enables such vegetable masses to bid defiance to the rocking waves; but what are these to the submarine forests in the channels of Tierra del Fuego, where the Macrocystis pyrifera rises from depths of from one hundred and fifty to two hundred feet, and then continues to float many fathoms on the surface of the sea!

'I know few things,' says Mr. Darwin, 'more surprising than to see this plant growing and flourishing amidst those great breakers of the western ocean, which no mass of rock, let it be ever so hard, can long resist. The stem is round, slimy, and smooth, and seldom has a diameter of so much as an inch. A few taken together are sufficiently strong to support the weight of the large loose stones to which in the inland channels they grow attached, and some of these stones are so heavy that, when drawn to the surface, they can scarcely be lifted into a boat by one person.' Fancy how beautifully calculated the strength of the resistance must be to withstand the vast strain of such a sea! No doubt many a Macrocystis is torn from the spot on which it grew and cast into the open ocean; but in spite of storm and breakers, the species maintains itself from century to century, for the strength with which it clings to the naked rock, and faces the fury of the elements, has been poised by the wisdom of a God.

Very different from the roots of the rock-bound Algæ are those of the Zostera marina, or Grass-wrack, a flowering sea-plant, which forms extensive submarine meadows on sandy shores. On this loose soil a simple superficial attachment would have been of no avail, but the long creeping stems of the Grass-wrack send forth long roots at every joint, which, plunging deep into the sand, are most admirably adapted for securing a firm establishment on this unstable foundation.

As under the shelter of the Laminariæ, thus also a host of marine animals and plants live and flourish under the green carpet of the submerged meadows of the Zostera, and thus in both cases the existence of a little world ultimately depends upon the peculiar structure of the roots of the protecting plant.

Ascending from these submerged forests and meads to the sand-dunes which on many flat coasts oppose an invincible barrier to the stormy ocean, we here also find plants eminently adapted, by the structure of their roots, for flourishing on a loose and drifting soil. Of these the sand-reed (Ammophila arundinacea), which naturally grows on the sandy shores of Europe, is one of the most remarkable. Its roots penetrate to a considerable depth, ramifying in all directions and forming a complete system of rope-work, which soon binds together the loosest sands and firmly attaches the plant, while its strong tall leaves protect the surface of the soil from drought, and afford shelter to small plants, which soon grow between the reeds, and gradually form a new green surface on the bed of sand.

But for the sand-reed the sea-winds would long since have wafted the drift-sand of the dunes far into the interior of the country, and converted many a fruitful acre into a waste; but that invaluable grass opposes its stubborn resistance to the most furious gale. Like a radical democrat, the wind would willingly reduce all to one common level, but the Ammophila, an obstinate conservative, opposes an indefatigable resistance to its fury, and, after a war of centuries, still lines the flat coast with long undulating chains of protecting sand-hills.

In the deserts and steppes of South Africa we also find a number of plants peculiarly fitted, by the formation of their roots, for the arid soil on which they grow and flourish. Thus creepers abound, which, having their roots buried far beneath the surface, feel but little the effects of the scorching sun. Those having tuberous roots are particularly abundant, a structure evidently intended to supply nutriment and moisture to the plant when, during the long droughts, they can be obtained from no other source.

In his description of the Kalahari desert, Dr. Livingstone mentions one of these plants, named *Leroshua* by the native Bechuanas. It has linear leaves and a stalk not thicker than a

row's quill; but, on digging down a foot or eighteen inches eneath, the root enlarges to a tuber often as big as the head of young child, which, on the rind being removed, is found to e a mass of cellular tissue filled with fluid much like that in a oung turnip. Owing to the depth beneath the surface at which t is found, it is generally deliciously cool and refreshing. Thus, ven in the desert, the bounty of the Almighty not only disposes he organisation of the plants so as best to secure their own xistence, but also raises them as sustenance for man; for without their succulent roots these barren and poverty-stricken lands would be all but uninhabitable.

The creeping plants of the desert serve, moreover, a double purpose; for besides their use as food, they fix, by means of the extensive ramifications of their roots, the constantly shifting sands, thus rendering services similar to those of the sand-reed on the dunes along the sandy coasts of the North Sea.

Those trees which naturally grow in situations where they are exposed to all the fury of the winds are invariably provided with roots of a corresponding power of resistance. On the brow of the northern hills the centenary fir defies the wintry blast; his strong vertical root dives deep into the crevices of the soil, or embraces the rock with sinewy arms. The proud columnar trunk, with its vast crown of foliage, rocks to and fro in the storm, but withstands its utmost efforts. The noble oak also is a match for the most terrific tempests, until the decay of old age has eaten its way into the trunk or roots, and undermined the venerable giant's strength.

The large high-stemmed palms penetrate, while germinating, to ... pth of three feet before the roots begin to spread, while the palms of lower growth, that do not require so firm an anchorage in the soil, send forth their roots near to the surface. When we consider that the cocoa-nut tree, which bears its magnificent tuft of colossal fronds and heavy racemes on the top of a slender shaft one hundred feet high, thrives best on the sea-shore, where the tropical hurricane has full play for its utmost fury, we can form some idea of the admirable foresight which gave its roots the necessary strength to resist the leverage of so prodigious a weight.

Trees with more superficial roots, such as the common pine, which scarcely penetrates into the soil to a greater depth than

two feet, grow either in less windy situations, or find mutual protection in the social life of the forest. Surrounded by comrades which break the power of the storm, their topmost crowns alone bend under the blast, while the lower branches remain unmoved: above, the legendary wild huntsman of the woods may rave in pursuit of his phantom game; below, the wanderer threads his way through the green arcades, and scarcely feels the motion of the air.

In the tropical forests the griping power of the roots is frequently assisted by the climbing plants, which, like the rigging of a ship, bind or unite as it were a large number of trees into a single body. While in the East Indian thickets the ratans ascend the highest summits of the forest, so as to be able to spread out their palm-like topes in the sunshine over the waving sea of verdure beneath, the paulinias, the bannisterias, the bignonias, and many other allied creepers, climb from branch to branch in the Brazilian woods, until their blossoms mix with the crowns of the giant trees. Often three or four of these bush-ropes, like strands in a cable, join tree to tree; others, descending from on high, take root as soon as their extremity touches the ground; while others send out parallel, oblique, horizontal, and perpendicular shoots in all directions, forming so intricate a network, that in this maze of vegetation it is utterly impossible to discover the trailing stem of the liana, whose flowers are seen expanding above in all their purple beauty. Frequently trees more than a hundred feet high, uprooted by the storm or undermined by the swelling river, are stopped in their fall by these amazing cables of nature, and are thus still enabled to send forth vigorous shoots, though far from their perpendicular, with their trunks inclined to every degree from the meridian to the horizon. Their heads remain firmly supported by the bush ropes, many of their roots soon refix themselves in the earth, and frequently a strong shoot will sprout out perpendicularly from near the root of the reclined trunk, and in time become a stately tree.

In several plants whose original roots do not seem adequate to support their increasing size, or which grow in situations where great and peculiar powers of resistance are required, new roots issue in a truly wonderful manner from the stem or the lower branches, and, fixing themselves in the ground, serve as

additional props to the weatherbeaten trunk. On viewing this miracle of nature, one might almost be tempted to adopt the belief of the ancient Greeks, and imagine each of these wonderful plants to be animated by a dryad, directing it to adopt the best means for securing its existence.

Fringing the estuaries of rivers or the shallow lagoons of the tropical zone, and incessantly exposed to the flux and reflux of the tides, the mangroves would hardly have been able to maintain themselves on so uncertain a soil, if the extraordinary growth of their roots had not admirably adapted them for securing a footing on the unstable brink of the ocean.

As the young mangrove grows upwards, pendulous roots issue from the trunk and inferior branches, and ultimately strike into the muddy ground, where they increase to the thickness of a man's leg; so that the whole has the appearance of a complicated series of loops and arches from five to ten feet high, supporting the body of the tree like so many artificial stakes. It may thus easily be imagined what dense and inextricable thickets, what incomparable breakwaters, plants like these, through whose mazes even the light-footed Indian can only penetrate by stepping from root to root, are capable of forming.

Where plants of a peculiar growth spread over large tracts of sea or land, we frequently find their influence extending far beyond the limited sphere of their individual life. Thus we have seen a whole little world of animals depend upon the existence of the gigantic fuci of Tierra del Fuego, and have noticed the important agency of the Ammophila in fixing the drift-sands and securing large tracts of fertile country, and thus also we find that the peculiar growth of the mangroves has a vast influence in promoting the increase of land at the expense of the maritime domain. Their matted roots stem the flow of the waters, and retaining the earthy particles that sink to the bottom between them, gradually raise the level of the soil. As this new formation progresses, thousands of seeds begin to germinate upon its muddy foundation, thousands of cables descend still further to consolidate it, and thus foot by foot, year after year, the mangroves extend their empire and encroach upon the sea. The enormous deltas of many tropical rivers chiefly owe their immense development to the unceasing expansion of these littoral woods, whose influence deserves the full attention of the

geologist when describing the ancient and eternal strife between the ocean and the land.

A similar formation of pendulous roots distinguishes the screw-pines, those singular plants whose foliage resembles that of the palm or bromelia, while their fruits remind one of the cones of the fir-tree or the pine. The older trees which require this additional support send forth their aërial roots in so opportune a manner that one might suppose them gifted with a peculiar instinct. For if the screw-pine, as is frequently the case, reclines to one side, the pendulous roots not only exclusively grow in this direction, which chiefly requires to be propped, but seem even able to choose the most proper places for their attachment.

The screw-pines grow on a sandy as well as on a rocky soil, for their roots spread out in considerable ramifications, and penetrate into the smallest cavities or crevices of the stony ground. They frequently grow in fantastic forms on the brinks of precipices overhanging the abyss, and then again twist their branches into a vertical position. Content with the most meagre soil, their frugality and the ease with which they strike root render them extremely serviceable in paving the way for a more luxurious vegetation on rocks or sandy shores. Thus they are widely spread on low islands and coasts throughout the whole tropical zone, where the lively green of their long ribbon-like leaves and the glowing crimson of their fruits contribute in a great degree to the beauty of the landscape.

But of all the plants which support themselves by means of pendulous roots, there is none more remarkable than the beautiful and stately Banyan, the vegetable wonder of India. Each of these marvellous trees is in itself a grove, and some of them are of astonishing size, as they are continually increasing, and, contrary to most other animal and vegetable productions, seem to be exempted from decay, for every branch from the main body throws out its own roots, at first in small tender fibres, several yards from the ground, which continually grow thicker, until by a gradual descent they reach its surface, where, striking in, they increase to a large trunk and become a parent tree, throwing out new branches from the top. These in time suspend their roots, and receiving nourishment from the earth, swell into trunks, and send forth other branches, thus continuing in a state

of progression so long as the first parent of them all supplies her sustenance. No wonder that the pious Hindoos are particularly fond of this glorious tree, and that they consider its long duration, its outstretching arms, and overshadowing beneficence as emblems of the Deity, of whose wisdom and power it is one of the most striking monuments.

Admirable as holdfasts or anchors, whose iron grasp enables the giants of the forest to brave the storm, the roots are equally remarkable as the organs which extract the nutritious particles from the soil and provide the plant with its necessary food. All our forest trees germinate with a chief or vertical root; but as lateral branches frequently acquire a more robust growth than the central stem, thus also we find that in many cases the lateral or side-roots become stronger and more extended than the parent root from which they sprung. In older trees a difference between the original or vertical root and its lateral embranchments can thus with difficulty be traced; and even in the oak, the beech, and the fir, which during the first year of their life possess a preponderating central root, this is not seldom at a later period far outgrown by its embranchments, each of which, under favourable circumstances, seems able to become the chief food-provider of the plant: a most wise and admirable provision, for as the trees are immovably bound to the soil, and only able to find nourishment as far as their roots can reach, they could not possibly have attained a great age or a colossal size, had they not been endowed with the faculty of extending their subterranean organs of nutrition in all directions, of conquering as it were new tributary regions, corresponding with the increase of their wants. It is only through the delicate radical filaments which proceed from the larger root-fibres that plants derive their nourishment from the earth; for experiment has proved that a herb will perish in the midst of water if the ends of its roots are raised above the surface. Each of these fibrils is enveloped in a sheath of cellular substances, and terminates with a peculiarly succulent tissue, forming what is termed the *spongiole*, where the process of absorption goes on with the greatest activity. Frequently the delicate fibrils are also covered with extremely fine hygroscopic hairs, destined to augment the absorbing surface. Thus endowed with the property of appropriating the nutritious juices of the

earth in its immediate vicinity, the growing spongiole gropes its way farther and farther, branches out in every direction, and constantly coming into contact with new portions of soil, extends the territory subservient to the wants of the plant. Well may we praise the beauty of the green canopy of the woods and the mighty columns which bear aloft those verdant domes; but let us also pay the tribute of our admiration to those humbler organs, whose incessant activity gathers in obscurity and darkness the materials of the grove, which but for them would never have so proudly crested the hill or so beautifully diversified the plain.

Yet the roots, although ever so well formed for providing the plant with nourishment, still required the assistance of peculiar physical and chemical agencies to be able to perform their functions. All plants of a higher order can, as is well known, thrive only in a soil which partly consists of the remains of a lower or preceding vegetation; the stately monarch of the woods rises upon the ruins of many generations of trees or shrubs of a humbler growth, and the corn-field requires fertilising manure to be able to reward the labours of the husbandman. The rain which irrigates the field, the meadow, or the wood, penetrates into the ground, imbibes the soluble salts contained in the vegetable mould or humus, is absorbed by the spongioles of the roots, and, ascending into the vessels of the trunk and branches, saturates the whole plant with nutritious substances. But rain frequently falls either after prolonged intermissions, or in much greater abundance than the immediate wants of vegetation require; and in both cases the plants must have suffered either from an insufficiency of moisture or from its excess, washing away the nutritious salts contained in the soil, if their healthy growth, nay, their very existence, had not been protected by the admirable properties of the humus. For this wonderful substance, or rather mixture of mineral and vegetable substances, attracts water so strongly that it not only prevents the too rapid evaporation of the rain or dew, but actually condenses the aqueous vapour contained in the air, and is thus enabled constantly to renew the sources from which the thirsty plant derives its sustenance.

As may be supposed, chemical decompositions and changes are perpetually going on among the substances of which every

fertile soil is composed. Thus, for instance, carbonic acid, ammonia, and several vegetable acids are constantly forming, while decomposition proceeds in the mould or manure, and by combining with the lime, iron, magnesia, silica, and other mineral portions of the soil, give birth to a variety of soluble salts, all fit to nourish and enter into the composition of plants.

No human eye has as yet been able to pierce all the mysteries of these chemical changes, but so much is certain, that they perfectly agree with the wants of vegetation, and that this beautiful coincidence between the chemical affinities of the soil and the requirements of organic life is another evident proof that the various powers of nature are all instruments of harmony in the hands of one Almighty power.

The nutritious salts thus formed would have been in a great measure lost for the purposes of vegetation, if the humus had not attracted them with a still greater power than that which it exhibits towards water. However abundantly the rain may fall, however greedily it may be absorbed by the inferior strata, the soluble substances are retained by the superficial layers of mould as by a sieve, and only the pure water percolates. The fertility of our fields, the luxuriant foliage of our woods, the perennial verdure of our meadows, depend in a great measure upon this wonderful physical property; for vegetation could never have attained its full development, if mould, like sand, had possessed no binding power over the nutritious particles of the soil.

The decomposition of the mould and the chemical changes that take place in the mineral substances of which it is partly formed, naturally proceed more rapidly, when the loosened and porous earth, which at the same time allows the *spongioles* of the roots to ramify more easily in all directions, permits the air to penetrate more freely into its interstices. Hence the evident utility of ploughing and digging; but these fertilising operations, which the labourer imperfectly performs with so much fatigue and expense, are executed with the utmost perfection and on the grandest scale by the power of winter.

As I have already mentioned in a previous chapter, water possesses the remarkable property of expanding as soon as it assumes the solid form of ice; so that when the humid soil becomes hard under the influence of frost, the moisture con-

tained in the minute crevices of the stones or the interstices of the soil thoroughly loosens the cohesion of the ground. On the return of spring, warmth, moisture, and air are thus better able to penetrate below the surface, and to awaken the germs of dormant life. In the Arctic regions, where winter frequently holds vegetation for months in iron bondage, this inclement season is at the same time one of its greatest friends, not only through the protecting mantle of snow which it spreads over the earth, but chiefly through the mechanical division of the soil which it causes. Thus death becomes the parent of life; and thus divine wisdom has made dreary winter the active helpmate of the short summer of the northern regions.

The roots of one plant do not rob the soil of the same mineral substances as those of another, for the various families of plants are not constructed of identical materials. Thus the grasses and all our cereals chiefly require silica for their nourishment; the pea and the lupin, chalk; the potato and the turnip, potash; the vine, soda; as the chemical analysis of their respective ashes proves. If plants of the same class were cultivated year after year on the same spot, the soil would soon be exhausted of the particular mineral substances they require, while by a judicious alternation of silica, potash, or chalk plants, it gains time to replace the mineral particles that have been withdrawn from it by the preceding crops.

If all plants absorbed the same mineral substances, the fields which now yield an annual return must frequently have lain fallow until the slow progress of mineral dissolution had repaired their losses; and consequently the same extent of territory could only have been able to feed a much smaller population. Thus we see that the wealth and power of all agricultural nations, and, consequently, also the progress of civilisation, depend in a great measure upon the relative importance of the various mineral portions of the soil to the different plants cultivated by man.

CHAPTER IX.

THE STEMS OF PLANTS.

The various Growth of Trees.—Internal Structure of Plant-stems.—Wood and Fibrous Cells.—The Shafts of Palms.—Climbing-plants.—Their various Modes of Attachment.—Tree Buttresses.—Defences of Plants.—Thorns.—Prickles.—Harmonies between the Trunks of Trees and the Wants of Man.—The Voices of the Forest.

How different the growth and stature of our forest-trees! Here the fir symmetrically raises its stately pyramid to the skies; there the oak widely extends its sturdy branches, like arms, ready to give battle to the storm. The beech, the elm, the poplar, the willow, the birch, have each their own well-defined individuality, and enhance the beauty of the landscape by their picturesque contrasts. The same pleasing variety strikes us in plants of humbler pretensions. This shrub has but a few vertical shoots, while its neighbour branches out in all directions; here growth tends ambitiously upwards; there it humbly creeps along the ground; here it confronts you with a military stiffness, as if determined rather to break than to yield; there it appears with a courtier-like pliability, ever ready to bend as the wind blows.

But, however different its growth may be, the trunk or stem of a plant is in every case admirably proportioned to the weight it has to carry or to the resistance it has to encounter, and in every case its texture has been made to harmonise with its task. Thus, on examining the internal structure of our forest trees, we find their woody fibres, which are long and pointed at both ends like spindles, firmly wedged into each other, an arrangement which of course gives the fabric of the trunk or branches a greater power to resist the violence of the wind.

Every year our forest trees add a new concentric layer or ring to their circumference, so that the strength of their axis

increases in the same proportion as the size of the crown; but the palms of the tropical zone have a different growth, as without any very perceptible increase in the diameter of their stem, they rear their colossal fronds higher and higher into the air. Yet, in spite of their comparatively slender trunks, and their towering stature, which is surpassed by that of but few other trees, they as effectually withstand the pressure of the storm as our firs or oaks, or as the dicotyledonous giants of their own zone, for their fibrous cells, which unite a remarkable degree of toughness with a considerable pliability, are interlaced so firmly at or near the surface of the trunk, where they are most compactly arranged, that they are enabled to bend without breaking, to bow down before the hurricane, and to rise again as soon as its fury has passed.

In the climbing or creeping-plants, whose thin and delicate stems are quite out of proportion to their weight, this want of self-supporting strength is compensated in various ways; so that, in spite of their apparent weakness, they are able to carry their heads as high as if they rested on colossal trunks. Some of them embrace other plants by growing in a spiral direction, as, for instance, our beans and hops; others, like the ivy, emit from their stem short aërial roots, which serve as hold-fasts in the crevices of old walls or trees; and others, again, like the vine, climb upwards by means of tendrils, which, growing out of the axillæ of the leaves, wind round neighbouring objects, and prop the plant as it ascends.

The tropical rattans, those remarkable climbing palms, whose rope-like stems often consist of a couple of hundred joints, each two or three feet long, and bearing at every knot a feathery leaf, rest so firmly upon the branches of the trees by means of the strong barbed thorns with which the petioles of their leaves are armed, and interlace themselves so frequently, that it is extremely difficult to detach them from their hold. Thus supported, they climb to the summits of the highest forest trees, and while it is impossible to distinguish their creeping stems from the intricate tangles of the matted underwood, their palm-like topes expand in the sunshine, the emblems of successful parasitism.

Other tropical climbers, again, have neither thorns nor tendrils to support them, but, as soon as they have found a stay in some neighbouring tree, they begin to extend over its surface

like a plastic body; for, while the stems of most other plants generally assume a cylindrical form, these wonderful climbers have the peculiarity of divesting themselves of their rind when brought into contact with an extraneous body, and of spreading over it, until they at length enclose it in a tubular mass. When during this process the powers of the original root are weakened, the stem sends forth new props to restore the equilibrium, and thus the parasitic race continually acquires fresh strength, while the incarcerated trunk is stifled and destroyed.

Several species of fig-trees are peculiarly remarkable for this destructive property, and from the facility with which their seeds take root where there is a sufficiency of moisture to permit of germination, are formidable assailants of ancient monuments.

In many tropical trees which, struggling for air and light in the dense thicket of the forest, attain a prodigious altitude, or from the colossal expansion of their branches require steadying from beneath, we find buttresses projecting like rays from all sides of the trunk. They are frequently from six to twelve inches thick, and project from five to fifteen feet; and as they ascend they gradually sink into the bole and disappear at the height of from ten to twenty feet from the ground,—a beautiful provision, which effectually protects the trees from the leverage of the crown, by which they would otherwise be uprooted.

Our annual herbs, which from their inconsiderable height are less exposed to the fury of the wind, naturally require no solid ligneous stem for their support. Many grow under the covering shade of some powerful protector; while others find adequate powers of resistance in the long and tough fibrous cells with which their stems are furnished.

The flax and hemp plants of our northern Flora, the Phormium tenax of New Zealand, and the Musaceæ and Bromeliaceæ of the tropical zone, are peculiarly distinguished by this fibrous texture, which, besides serving for their own preservation, renders them also eminently useful to man.

Although unable to move from the spot, and thus to avoid by a timely flight the attacks of their enemies, the plants have not been left defenceless against man and the herbivorous animals of the woods. Thus many of our native shrubs are guarded by ramparts of thorns and prickles, but the spines of our hawthorns and bramble-bushes give but a faint idea of the size which these

defensive weapons attain in the tropical zone. The cactuses, the acacias, and many of the palm-trees, bristle with sharp-pointed shafts, affording them ample protection against the attacks of hungry animals, so that they might appropriately be called vegetable hedgehogs or porcupines.

The melon-cactus of the South American llanos or savannahs conceals its juicy pulp, pleasant to man and beast, under one of these formidable panoplies. Guided by an admirable instinct, the wary mule strikes off with his fore-feet the long sharp thorns of this remarkable plant, the emblem of good nature under a forbidding exterior, and then cautiously approaches his lips to feast upon the refreshing marrow. Yet, in spite of every precaution, the attempt to quaff from these alluring sources is frequently attended with danger, for mules are often met with that have been lamed by wounds from the formidable prickles of the cactus.

The black twigs of the buffalo-thorn (Acacia latronum), a low shrub abounding in northern Ceylon, are beset at every joint by a pair of thorns, set opposite each other like the horns of an ox, as sharp as a needle, from two to three inches in length, and thicker at the base than the stem on which they grow; and the Acacia tomentosa, another member of the same numerous genus, has thorns so large as to be called the jungle-nail by Europeans, and the elephant-thorn by the natives. In some of these thorny plants, the spines grow, not singly but in branching clusters, each point presenting a spike as sharp as a lancet; and where these shrubs abound, they render the forest absolutely impassable even to animals of the greatest size and strength.

The rattans and bush-ropes impede the wanderer's progress not only by the tough cordage they twine from tree to tree, but also by the strong hooks and thorns with which they are generally armed, so that every attempt to force a passage would be severely punished with torn clothes and bloody hands, and large knives or heavy scythe-like axes are necessary to clear the way.

Some plants are protected by thorns only up to a certain height. The Caryota horrida, a palm which raises its crown fifty feet above the surface of the soil, is so thickly studded with formidable thorns to the height of six or eight feet, that it is hardly possible to see the bark; further upwards, where defence is no longer necessary, the trunk is unarmed. The thorny

plants, which are frequently so inconvenient or injurious to man, are often used to protect his fields and plantations against wild beasts and robbers, or even as bulwarks against hostile invasions. Thus, Sir Emerson Tennent informs us that, during the existence of the Kandyan kingdom, before its conquest by the British, the frontier forests were so thickened and defended by dense plantations of thorny plants as to form a natural fortification impregnable to the feeble tribes on the other side; and at each pass which led to the level country, movable gates, formed of the same thorny beams, were suspended as an ample security against the incursions of the naked and timid lowlanders.

The trunks and stems of the plants are far more important to man than their roots, and in fact utterly indispensable to the progress of civilization. The circumstance that a large proportion of the cells of which they are formed acquire a ligneous texture during the progress of their growth, or change into tough and pliable fibres of a very considerable length, is of paramount importance to the welfare of man; for what would have been his social condition if the reign of Flora had been confined to plants of a humble growth or brittle texture. Navigation would have remained unknown to him; like a wild animal, he would have been obliged to live in burrows or in caves; he would never have been enabled to manufacture any of the instruments which agriculture, industry, and the mutual intercourse of nations absolutely require; he would always have remained a miserable savage, the wretched lord of a wretched inheritance.

The difference of texture and consistency in the wood of different trees is likewise an object of high importance to man. One kind of wood recommends itself to his notice by its strength and hardness, another by its pliability; a third by the ease with which it can be worked; a fourth by its lightness: and thus the carpenter, the ship-builder, the coach-maker, the turner, and many other artizans find each of them the most suitable materials for their several purposes among the various trees of the forest.

But the trunks of the trees are useful to man not only by their solid and fibrous parts, but frequently also by the juices which they contain, or the substances deposited in their cellular tissue. Thus, they provide him with an amazing variety of dyeing

substances, of resins, and gums. In the rind of the Cinchona-trees he finds quinine, the only substance which opposes an effectual resistance to the fever and ague; and that of the cinnamon tree surpasses all other spices in flavour. The bark of the cork-tree gives him the necessary material for preserving the rich produce of his vineyards, and that of the common oak with the astringent juices he requires for tanning the hides of his cattle. Whole nations live almost exclusively upon the pith of the sago palm, and when a deep incision is made in the trunk of the wonderful cow-tree of Guiana, it pours forth an excellent milky fluid in such abundance as to relieve the traveller's thirst. Thus man finds innumerable treasures in the trunks of trees. Thus there is a wonderful harmony between the various wants of cultivation and the life of the forest.

When the wind swept through their sacred groves, our pious ancestors fancied they heard in the moaning of the agitated leaves, in the rustling of the branches, the voice of an invisible God—and should these awful sounds awaken no echo in our breasts, should we remain insensible to a language which so eloquently proclaims the august Being, who, in his infinite power and wisdom, has raised those beautiful temples of Nature for the use of man?

CHAPTER X.

THE LEAVES OF PLANTS.

The chief Ornament of Spring.—Internal Structure of Leaves.—The Cuticle.—Stomata and Air-Cells.—Opening and Closing of the Stomata.—Pliability and resisting Powers of the Leaves.—Their Stems.—Dionæa Muscipula.—The Mimosas.—Enemies of the Leaves.—Their Defences.—Hairs.—Prickles.—Secretions.—Harmonies between Leaves and Insects.

How beautiful the lively verdure of spring, how it refreshes the eye after the gloom of winter, and where shall we find in summer a more delicious shade than under the green canopy of the woods? As the year declines, the autumn tinges the forests with the richest colours; and even in winter, the dark evergreens form a picturesque contrast with the dazzling snow, so that at all seasons of the year the landscape is adorned by the foliage of the trees.

Were the leaves restricted to a few simple forms, to a small number of tints, they would still be one of the chief ornaments of Nature; but their decorative power is wonderfully enhanced by their endless varieties of shape, by their infinite shades of colour. Of all the herbs we may gather on our excursions, not one is like the other; every new species of tree that meets our eye has its own peculiar foliage, and were we to wander through all the zones of the earth, every new plant on our way would greet us with a new form of leaf.

Thus, the delicate organs of vegetable life have been made, not only to minister to the wants of the plants of which they form a part, but also to afford a constant gratification to our sense of the beautiful, and to raise the mind by the delight which their every varying contrasts afford, to Him who made them.

Conjointly with the roots, the leaves serve to nourish the plant; they inhale and elaborate the gases and vapours of the

atmosphere, they are its respiratory organs, its lungs; their expansion and their number correspond with its vital activity. Plants living in the shade, or restricted to a tardy growth, can subsist with a few scanty leaves, but the monarchs of the woods, or such plants as powerfully strive towards the sun, require a vast extent of foliage to satisfy the wants of a widely-branching crown, or of a rapid vegetation. In a couple of months the herbaceous juicy stem of the plantain shoots up as thick as a man's body, to the height of fifteen or twenty feet; but the colossal leaves of the giant harmonise with this amazing rapidity of growth, as they frequently attain a length of fifteen or twenty feet with a breadth of two feet or more.

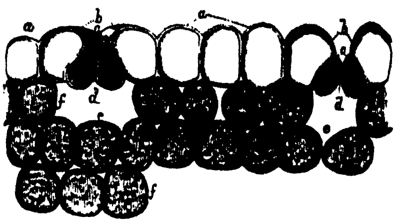
As in plants of such rapid growth as the Musaceæ all the efforts of vegetation must necessarily tend to develope as fast as possible an immense foliaceous surface, the leaves of those colossal herbs are remarkably thin; but as they are also very much exposed to boisterous winds, their middle rib contains a number of extremely long and tough fibres, so that, although a slight breeze is able to tear them into transverse shreds, by which their own nutrition and their serviceableness to the plant are by no means impaired, yet even a storm cannot snap them asunder; and thus, by a wonderful provision, the extreme fragility resulting from an *extensive* growth of uncommon rapidity, is found united with immense powers of resistance.

The internal structure of the leaves is as wonderful as their external variety and beauty. With the exception of such as grow under water, the leaves of all the flowering or phanerogamic plants are covered with a colourless cuticle consisting of cells, the walls of which are flattened above and below, whilst they adhere closely to each other laterally, so as to form a continuous stratum. Their shape is different in almost every tribe of plants, and their walls, especially on the side nearest the atmosphere, are generally thickened by a waxy deposit, impermeable to fluids, the retention of which within the soft tissues of the leaf is obviously the purpose to be answered by the peculiar organisation of the cuticle.

In most European plants the cuticle contains but a single row of thin-sided cells, whilst in the generality of tropical species there exist two, three, or even four layers of thick-sided cells, which give the leaf an almost leathery consistence. This difference of structure is most beautifully adapted to the

various climates in which these plants have been respectively destined to flourish, for the thin cuticle of a species indigenous to temperate climates, would not have afforded a sufficient protection to the interior structure had it been exposed to the vertical rays of a tropical sun, whilst the diminished heat of this country would scarcely overcome the resistance of the dense and *non-conducting* tegument of a species formed to exist in tropical climates. Nor must we forget that the thickness of the badly-conducting cuticle serves also to protect the leaves of the equinoctial plants against the great difference of temperature which frequently exists between the heat of the day and the chilly coolness of the night, a difference much greater than that which takes place in the temperate regions.

As the cuticle is impermeable to air, it may well be asked how the leaves are able to perform their respiratory functions; but the enigma is soon solved on examining a leaf through a powerful microscope, for then the cuticle is seen to be pierced with numerous pores, or *stomata*, leading into *lacunæ* or *air-chambers*, small open spaces situated in the green cellular tissue of the leaf, and thus affording a passage to the atmosphere.



a.a, cells of the cuticle; *b.b*, cells at the sides of the stomata; *c.c*, small green cells placed within these; *d.d*, openings of the stomata; *e.e*, lacunæ or air cells; *f.f*, cells of the parenchyma.

In general, the stomata are not so numerous on the upper as on the under surface of the leaf; frequently even, as for instance in the oak, the beech, the birch, and the alder, they are entirely confined to the latter. In the erect leaves of the grasses they are about equal on both sides; in leaves floating on the surface of the water they are found only on that side which is exposed to the air; and in submerged leaves they are, with but few exceptions, completely wanting. Generally, they are least numerous in succulent plants, whose moisture is destined to be retained in the system; whilst they abound most in those species in which a rapid absorption and exhalation of the fluids takes place. In the Hydrangea, for instance, there are no less than 16,000 stomata in every square inch of the under surface of the leaves;

in the black elder, 63,000; in Iris germanica each surface has nearly 12,000 stomata in every square inch; and in Yucca, each surface has 40,000. What wonders does a close inspection thus reveal in the structure of a leaf whose surface appears uniform and unbroken to the naked eye. On that side of the leaf where the stomata and the corresponding lacunæ chiefly abound or exclusively exist, the green cellular parenchyma is always of a looser texture, whilst on the opposite side, where the stomata are either less abundant or entirely wanting, it is more compact. Hence the under surface of the leaves is generally of a less intense green than the upper one, where the cells are more closely congregated.

The stomata are destined to admit air, not water, which by drenching the leaf would entirely interrupt the process of respiration. This danger is effectually guarded against by the boundary-cells of the stoma, (*d.d,*) which, from their swelling or expanding in moist weather by the absorption of humidity, are able entirely to close the opening, so that no rain can penetrate into the air-chambers, and thus this simple hygroscopic property renders here the services rendered by muscular contraction in closing the cavities of the animal body.

Where shall we find pliability and firmness more beautifully combined than in the structure of a leaf? A slight breath of air sets it in motion, and this circumstance is naturally very favourable to the respiratory process, as the perpetual agitation of the foliage brings it into contact with new sheets of air, and thus facilitates the exchange of oxygen and carbonic acid. But as the green cellular tissue of the leaf, in which the functions of respiration are carried on, is easily torn, a strong framework or skeleton was needed to give it the necessary support, and this is amply afforded by its ribs, which, consisting of bundles of strong, tough, and colourless vessels, proceed from a chief middle-rib, and ramifying over the whole surface, support the green-coloured cellular tissue as firmly as the trunk, subdividing into numerous branches, supports a vast crown of foliage.

To increase the mobility of the leaves without detriment to their strength, their mid-rib frequently forms a long stalk before merging into the body of the leaf, which, being thus freely suspended upon its slender and flexible support, easily gives way to the slightest disturbance of the air, as a ship at anchor gently rocks to and fro in the heaving and subsiding waters.

Where the foot-stalk of the leaf has to bear a considerable weight, and is moreover very much exposed to the wind, additional precautions have been taken for increasing its strength. Thus, the foot-stalks of the huge fronds of the cocoa-palm are inclosed in a tough web or network, which preserves them so well from breaking, that even after death they remain attached to the tree. In the flexible grasses we find the leaves embracing the stem with a sheath, which gives to both a much greater power of resistance, while in many herbs the sessile leaves are placed in such a manner that the rain or dew collecting on their surface flows down the stalk to the roots, where it is most needed. In several aquatic plants, the stalks of the leaves are ventricosely distended, so as to render them buoyant, and in many of the fuci, the large air-vessels with which the stem or the fronds are furnished, answer a similar purpose. These few examples sufficiently prove that it is not by a mere caprice of growth that some leaves are barely suspended from stalks, while others embrace the stem of the plant, but that every variety of form is made to answer an especial end. No plant has been neglected, none has been encumbered with useless or unappropriate organs, but each has received all that it required.

Some leaves have been gifted with a wonderful sensibility which seems almost to raise them to the level of animal life. Thus the Porliera hygrometrica foretels serene or rainy weather by the opening or closing of its leaves. Large tracts of country in Brazil are almost entirely covered with sensitive plants. The tramp of a horse sets the nearest ones in motion, and, as if by magic, the contraction of the small grey-green leaflets spreads in quivering circles over the field, making one almost believe with Darwin and Dutrochet that plants have feeling, or tempting one to exclaim with Wordsworth—

> It is my faith that every flower
> Enjoys the air it breathes.

The leaves of the Venus's Fly-trap (*Dionæa muscipula*), a marsh-plant of North America, are still more curious, as their wonderful contractility gives them an offensive power quite unique in the vegetable world. They are oblong, and divided by the mid-rib into two halves inclining towards each other, and beset on the upper surface and along the edges with long and stiff bristles. At the slightest touch the two halves

instantaneously clap together, the bristles on both sides fitting into each other, so that if a fly settles on an opened leaf it is immediately caught as in a trap, and forced to remain in its highly uncomfortable position as long as life lasts, for the least movement stimulates the contraction of the leaf.

In the Hedysarum gyrans, a leguminous plant of the East Indies, we even find something like voluntary motion, as the wings of the ternate leaves are constantly oscillating upwards and downwards, quite independently of any external stimulus, so that this wonderful plant seems absolutely invested with one of the chief attributes of animal life.

Thus, even in the vegetable kingdom, we find glimpses of a higher order of existence; as in our own natures we are able to trace the dawn of a superior spiritual world.

In consequence of the delicacy of their structure the leaves are exposed to innumerable hostile attacks; but it may well be supposed that organs of such vital importance have not been left unprotected, and that bounds have been set to the voracity of their enemies. Many are invested with a thick tomentose or cottony covering, others with hairs, bristles, or prickles. Sometimes these hairs bear little glandular bodies at their extremities, by the secretion of which a peculiar viscidity is given to the surface of the leaf, as in the Sundew (*Drosera*); in other instances the hair has a glandular body at its base, whose secretion is of an irritating quality, as, for instance in the Nettle, where the extremity of the hollow sting, being extremely brittle, breaks at the slightest touch, and suffers this corrosive fluid to escape.

The sharp, bitter, or acrid juices with which the substance of many leaves is saturated, as well as the strongly-scented volatile oils which others exhale from their surface, no doubt serve also as powerful means of passive defence.

Another circumstance favourable to the leaves is, that the attacks of many of their enemies are limited to a short space of time. Some insects feed only upon the first tender foliage of spring, so that a rapid vegetation outstrips their ravages: others make their first appearance towards the end of summer. During all these attacks the plant is incessantly active in repairing its incessant losses; its leaves are constantly extending their surface, or new ones are sprouting forth to replace those that

have been devoured, and, thus in spite of the large number and voracity of its enemies, the foliage is generally able to resist all their efforts.

Week after week the pastures are cropped by numerous herds, or mowed by the husbandman, and yet the grass never ceases to flourish, and after countless caterpillars and beetles have feasted upon the plenty of the forest, it still bears a luxuriant crown, until finally the winter scatters its foliage to the winds. This indomitable energy of vegetation, which not only supports itself, but a whole world of animals, and sets the ravages of centuries at defiance, is indeed one of the great wonders of creation!

In all climates we find a harmonious balance between insect and vegetable life. Towards the north, where the growth of plants is confined to a few months or even weeks, they have but few enemies to encounter; in the temperate zones hostility increases with the increase of vegetation, until finally, in the damp tropical lowlands, the herbivorous insects take the field in countless legions. But here, where the plantain raises its colossal shaft in eight or ten months to a height of twenty feet, where the bamboo grows at the rate of eighteen inches in twenty-four hours, and the same field yields three harvests in the course of the year, an amazing power of vegetation resists all these devastations; and here, also, the defences of the plants increase with their increasing dangers; for nowhere are the leaves better protected with hairs and spines, and nowhere do they elaborate more pungent juices or exhale more penetrating odours.

Thus harmony is everywhere maintained between the two great divisions of organic life, and thus firmly established on the laws of an All-wise Power, an eternal order reigns supreme amidst the conflicting interests of all created beings.

Where we see so much care bestowed upon the leaves, which are but simple individual organs, we may well expect to find still greater precautions taken for the protection of the buds, in which the foliaceous rudiments of a whole branch, or even of a whole plant, are contained.

A bud is seldom naked; generally it is invested with a panoply of thick scales of a coriaceous or fibrous consistence, and, moreover, frequently covered with hairs or impregnated with

resin. Under this comfortable mantle, which from its being a bad conductor of heat opposes an effectual resistance to the cutting winds or nipping night-frosts of early spring, the first tender leaflets are developed by the influence of the warming sun, as safely and securely as a brood of chickens under the fostering care of a hen. Slowly they swell within the little dungeon in which they are so providently inclosed; but as soon as they have burst their fetters, they expand with an astonishing rapidity, and in a few days the tree appears in the full beauty of its youthful verdure.

CHAPTER XI.

BLOSSOMS.

Their Functions.—Their Accessory and Essential Parts.—The Calyx.—The Corolla.—The Pistils.—The Anthers.—The Pollen.—Insects as Means of Fructification.—The Vallisneria Spiralis.

Nothing can equal the immense variety of flowers, their charming colours, or their delicious fragrance. How differently formed are the radiate aster and the hooded wolf's-bane, the bell-shaped campanula and the papilionaceous lupin, and yet it would be difficult to say which of them most pleases the eye.

The colours with which the flowers are adorned baffle description. The snowy whiteness of our fruit-trees adds new beauties to spring, and the purple heath invests the bleak and barren Highlands of the north with a magnificence equal to the warm tints of Italy or Spain. The humble daisy, the golden buttercup enamel our verdant meads, and every hue of the rainbow is reflected in the gay parterres of our gardens, or in the conservatories where Flora assembles her favourites from all parts of the world.

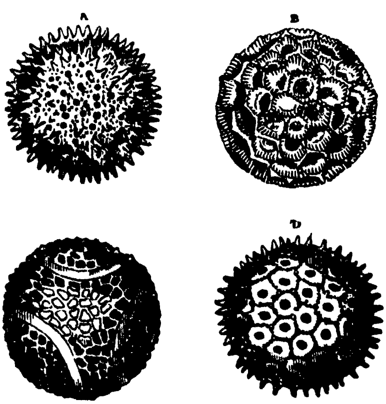
The foliage of many plants exhales an agreeable odour, but no leaf produces a balsam which can in any way equal the aroma of the violet or the rose, of the pink or of the lily of the valley. Without the flowers, the variety of perfumes which regale our sense of smell would be but small; without them its faculties of enjoyment would not have harmonised with the outer world.

But the corolla on which Nature has thus lavished all that can gratify the senses, plays after all but an accessory part in the economy of the vegetable kingdom, as, conjointly with the calyx, it merely serves as a protecting cover, or as an ornamental envelope to the pistil and to the stamina, which, though generally of a more humble appearance, are the essential organs

of fructification in all the higher plants. Thus, both the corolla and the calyx may be wanting, as for instance in the vast family of the grasses, which spreads in thousands of species over the face of the globe.

The pistil or pistils—for they vary in number from one to twelve, and sometimes more—commonly appear in the centre of the corolla, from which they rise like so many green columns. A pistil consists of three parts—the stigma at its upper extremity, which is sometimes globular, sometimes cleft, sometimes cross-shaped; the style or hollow pillar which supports the stigma; and the germen, or seed-bud, which forms its pedestal or base, and in which the germs or ovula are contained.

The stamens, which resemble threads, or pillars, usually stand between the corolla and the pistil, but are extremely various in their arrangement and number—a circumstance on which Linnæus founded his method of classifying plants. Some have but one stamen, others two, three, and so on up to ten, twelve, twenty, or even several hundreds. In some flowers we find the stamina standing apart from each other, in others united by their filaments into one or several sets; here they are all of equal length, there of unequal dimensions; sometimes they are attached to the inside of the calyx, sometimes to the corolla, to the receptacle, or to the pistil. They invariably consist of two parts, the *anther* and the *filament*. The anther is the summit of the stamen, and contains the mealy or powdery substance called *pollen*, which, brought into contact with the stigma, serves to fecundate the ovula contained within the germ. When come to maturity, the anthers open in various ways—longitudinally or transversely, or through the raising of a lid, or through numerous apertures, so that the pollen contained in its interior becomes free and covers its surface with a fine generally yellow-coloured powder.



Pollen-Grains of rosea; *b*, cobæa scandens; *c*, passiflora cœrulea; *d*, ipomœa purpurea.

If these golden cushions carried on *pillars of ivory* afford an agreeable spectacle to the naked eye, our admiration increases when we come to view the pollen-grains under a magnifying-glass—for every genus of plants has its own characteristic form of this fructifying dust, the surface of which is often most curiously marked. Its roughening by spines or knobby protuberances is a very common feature, and answers the purpose of enabling it to adhere more readily to the stigma.

These elegant little globes are so small that they generally attain a diameter of only 1-1,200th or 1-3,000th of an inch; while they are so numerous that frequently many thousands are brought forth by one single flower, and thus the seed we tread under foot produces with a boundless prodigality objects so exquisitely formed and modelled that the most skilful pencil can hardly do justice to their beauty.

Even the pollen-grain which the vernal wind carries in countless billions through the air, and which man scarce ever deigns to notice, is the work of a consummate master, a wonderful monument of Almighty power!

Although both the pistils and the stamina are essential organs of fructification, and seed can only be formed by their mutual co-operation, yet they are not always united in the same blossom. Sometimes, as in the birch, we find flowers of different kinds on the same plant, some bearing pistils and others stamens only; or, as in the willow and poplar, stamens on one plant and pistils on another; or, even as in the common ash, the same tree will bear flowers of three different kinds.

In most plants, however, the pistils and anthers are united within the same corolla, an arrangement which greatly facilitates the admission of the pollen to the stigma; and for the same purpose the stamina of most plants surround the pistilla, an arrangement which gives the pollen an opportunity of falling upon the stigma at every breeze of wind. In those flowers which stand upright, the stamina are higher than the top of the pistil, so that, as the pollen is specifically heavier than air, some of it must almost inevitably fall upon the stigma as soon as it detaches itself from the anther, while in those flowers which hang down or incline to one side, the pistil is longer than the stamina.

The flowers of most plants expand by the heat of the sun,

and close their petals in the evening or in rainy weather. The final cause of this is to keep the moisture from the pollen, lest it should be thereby coagulated, and of course prevented from falling or being blown upon the stigma. Thus, in the organisation of the hermaphrodite flowers, every circumstance which could possibly favour their fecundation has been most admirably attended to; and though those plants where the stamina and the pistils appear in separate flowers, or even on separate trees, might at the first view seem less well provided for, yet here also the pollen is made to reach the stigma as surely as if both had been produced within the same corolla.

To effect this object, Nature has two most efficacious agents at her disposal: the wind, and the insects, who by their friendly intervention seem desirous of making amends to Flora for the ravages they are perpetually committing on her domains. The bees are particularly useful in this respect, for, while sipping the sweet juice of the nectaries at the bottom of the flowers, they brush off the pollen from the anthers of one flower with their hairy bodies, and unconsciously convey it to the stigma of another. In the extensive families of the Asclepiadeæ and of the Orchids, insect intervention is not merely of assistance but absolutely necessary for their fecundation: as here the ripe pollen, instead of being a loose powder, forms a wax-like adhesive mass, which sticks fast to the honey-gathering insect, and could not otherwise be brought into contact with the stigma. In these flowers the nectaries are disposed in such a manner that, to be able to reach them, the insect must necessarily graze the stigma, and thus bring the fructifying pollen to the place where it is needed, an arrangement which plainly points to the direction of a higher hand.

As the moistening of flowers generally prevents their fructification, (for the pollen of but very few water-plants, such as the Horn-wort (*Ceratophyllum demersam*), and the Grass-wrack (*Zostera marina*), is not damaged by wet), most of the plants that grow below water emerge when their flowers begin to blow, and swim upon the surface till they receive their impregnation, and then sink down.

Thus in autumn, at the time of flowering, air is developed in the bladders, which here and there distend the linear leaves of the *Utricularia vulgaris* or Hooded Milfoil, a plant of frequent

occurrence in stagnant waters. Thus buoyed up, the blossom rises to the surface, and expands its large yellow petals in the atmosphere, but as soon as fructification is accomplished, the air of the bladders escapes or is absorbed, and the sinking *Utricularia* returns to its more congenial element. In other cases, where the depth of the water in which it grows is too great to allow the plant to rise to the surface, as, for instance, in many species of Water-wort (*Elatine*), and Water-plantain (*Alisma*), a bubble of air is secreted within the folded corolla at the time when fructification is to take place, and forms a subaqueous atmospheric chamber in which the process can be safely accomplished.

But the fructification of the *Vallisneria spiralis*, a common plant in the ditches of the rice-fields in Italy, is beyond all others curious. This herb grows in the mud, generally several feet below the surface of the water, and has its stamens and pistils on different flowers. The anthered flowers grow in short-stemmed compact knobs at the basis of the leaves, while the stigmate-flowers are seated on long stalks spirally contracted like a corkscrew. When the time of fructification approaches, the small anthered flowers detach themselves from their stalks, and swim about upon the surface, where they freely emit their snow-white pollen; while the stigmate flowers, in which a similar separation from the maternal plant was not admissible, gradually rise to the top by the unfolding of their spiral coils. As if prompted by an animal instinct, they are constantly moving on the surface, as though they were seeking the small anthered flowers, which are at the same time swimming about in considerable quantities. When fructification is completed, their long stalk again contracts into a spiral, and the flower, having no longer the contact of the water to fear, sinks again to the bottom, where the fecundated germ grows to maturity.

Thus a despised and troublesome weed shows us wonders in its organisation, which would be utterly incomprehensible if we did not attribute them to a divine and all-wise Creator!

CHAPTER XII.

SEEDS AND THEIR MIGRATIONS.

Defences of Seeds.—Their Dissemination over the Earth.—Feathers and Wings.—Cotton.—Influence of Water-courses.—Mangrove Seeds.—The Animals and Man as Disseminators of Plants.—Progress of Vegetation on the originally naked Rock.

CAN anything be more admirable than the provident care bestowed upon the seeds of plants? See how the sweet kernel of the walnut is inclosed, not only in a thick coriaceous astringent skin, but in a solid case of almost stony hardness; and how snugly the chesnut lies concealed, like a hedgehog under its bristly coat, until, when fully ripe, it bursts the bonds which held it in salutary confinement.

The tender seminal germs are not only protected by a dense envelope against the influence of the weather, so as to be able to remain for years in a state of dormant vitality; but they also find within the seed itself the albumen, the oil, the starch, the gluten, in one word, all the nourishment they require when under favourable conditions they first awaken into active life; and thus nothing is wanting for their equipment when, dropping from the parent stem, they launch forth to seek their own fortunes in the wide wide world.

From the sedentary nature of plants, they would have been menaced with extinction if nature had not provided means for the diffusion of their seeds over a vast area. As the spores of mosses, fungi, and lichens consist of an impalpable powder, the particles of which are scarcely visible to the naked eye, it is not difficult to account for their being dispersed throughout the atmosphere, and carried to every point of the globe, where there is a station fitted for their reception. Lichens in particular ascend to great elevations, sometimes growing two thousand feet above the line of perpetual snow, at the utmost limits of vegeta-

tion, and where the mean temperature is nearly at the freezing point. This elevated position must contribute greatly to facilitate the dispersion of those buoyant particles of which their fructification consists.

'The sporules of fungi,' says Fries, 'are so infinite that in a single individual of *Reticularia maxima* I have counted above ten millions, and so subtile as to be scarcely visible, often resembling thin smoke; so light that they may be raised perhaps by evaporation into the atmosphere, and dispersed in so many ways by the attraction of the sun, by insects, wind, elasticity, adhesion, &c., that it is difficult to conceive a place from which they may be excluded.'

Among the higher plants we find a great number of seeds furnished with downy and feathery appendages, enabling them, when ripe, to float in the air, and to be wafted easily to great distances by the most gentle breeze. Thousands and thousands may perish on the way, or fall upon a barren soil, but many, favoured by fortune, find a new home far away from the spot where their parents grew, and found new starting points for further emigrations. Thus many a plant may have been extirpated in its original seat and yet flourish in another country, reminding one of those ancient cities whose colonies still prosper, while they themselves have long since vanished from the earth.

It would be a difficult task to describe the various and elegant forms of the feathery appendages which serve to waft the seeds through the air. Nothing can exceed in lightness and beauty the downy tufts which surmount the grains of the dandelion, the thistle, the chickory, and so many others of our compound flowers; and though not one of them resembles the other, each fully answers its purpose. Here, as in every other case, the Creator has not only provided for the utility but also for the decoration of his works.

The seeds of many of our forest-trees are fitted for dispersion by means of an attached wing, as in the case of the fir-tree, the elm, the birch, the ash, the maple, so that they are caught up by the wind as they fall, and are carried to a distance. As winds often prevail for days, weeks, or even months together, in the same direction, this means of transportation may sometimes be without limits, and even the heavier grains may be borne

through considerable spaces in a very short time during ordinary tempests; for strong gales, which can sweep along grains of sand, often move at the rate of about forty miles an hour. The hurricanes of tropical regions, which root up trees and throw down buildings, may carry even the heavier fruits and seeds over friths and seas of considerable width, and doubtless are often the means of introducing into islands the vegetation of adjoining continents.

Whirlwinds are also instrumental in bearing along heavy vegetable substances to considerable distances. Slight ones may frequently be observed in our fields in summer, carrying up haycocks into the air, and then letting fall small tufts of hay far and wide over the country; but they are sometimes so powerful as to dry up lakes and ponds, and to break off the boughs of trees and carry them up in a whirling column of air. As this cause operates at different intervals of time throughout a great portion of the earth's surface, it may be the means of bearing not only plants but animals to points which they could never otherwise have reached, and from which they may then begin to propagate themselves again as from a new centre.

The long downy filaments which are appended to the numerous seeds of the Gossypias, or cotton-plants, deserve particular notice, as they not only waft them easily through the air, but serve also to clothe a large portion of the human race, and rank as the very first of all the world-wide importations of England. Liverpool and Manchester, with their train of minor stars, undoubtedly the scene of the most gigantic industry known in the history of man, owe their prosperity to the wings with which Providence has furnished the seeds of a small and otherwise unimportant family of plants.

Some seeds are dispersed by the sudden springing open of the elastic capsule in which they are contained. In this manner the seeds of the *Balsam balsamine* are jerked to a considerable distance, and the *Ura crepitans*, an Indian shrub, accompanies this action with an exploding noise which has been compared with that of a pistol shot.

In the dispersion of seeds, rivers and marine currents are not less instrumental than the atmospherical agencies. The mountain-stream or torrent washes down to the valley the seeds which may accidentally fall into it, or which it may happen to sweep

Erinus of the high mountains has been transplanted by the Rhone into the neighbourhood of Toulon. The broad and majestic river, winding along the extensive plain, and traversing the continents of the world, conveys to the distance of many hundreds of miles the seeds that may have vegetated at its source. Thus the southern shores of the Baltic are visited by seeds which grew in the interior of Germany, and the western shores of the Atlantic by seeds that have been generated in the central forests of America.

The marine currents even carry seeds over the broad bosom of the ocean from continent to continent. Fruits indigenous to America and the West Indies, such as that of the *Mimosa scandens*, the cashew-nut, and others, have been known to be drifted across the Atlantic by the Gulf-stream on the western coasts of Europe, in such a state that they might have vegetated had the climate and soil been favourable. Among these the *Guilandina bonduc*, a leguminous plant, is particularly mentioned as having been raised from a seed found on the west coast of Ireland.

On the shores of Orcadia, a sort of fruit commonly known by the name of *Molucca* or Orkney beans are found in large quantities, particularly after storms of westerly wind. These beans are the produce of West Indian trees, and find their way from the woods of Cuba and Jamaica by means of the Gulf-stream.

As the seeds destined for long aerial migrations are light, and frequently furnished with wings or with downy and feathery appendages, thus the seeds of the littoral plants, whose dispersion chiefly takes place through the instrumentality of aqueous agents, are generally provided with hard water-proof shells, so that they may be wafted over the vast ocean without losing their germinating power. Islands, moreover, and even the smallest rocks, play an important part in aiding such migrations; for when seeds alight upon them from the atmosphere, or are thrown up by the surf, they often vegetate and supply the winds and waves with a repetition of new and uninjured crops of fruit and seeds. These may afterwards pursue their voyage through the air or along the surface of the sea in the same direction. The number of plants found at any given time on

an islet affords us no test whatever of the extent to which it may have co-operated towards this end, since a variety of species may first thrive there, and then perish, and be followed by other chance comers like themselves.

Nothing can be more remarkable than the very peculiar manner in which the seeds of the Mangroves, those wonderful trees whose semi-aquatic reign extends along the margin of the tides, have been made to harmonise with the locality in which they are destined to thrive. They germinate on the branches, and, increasing to a considerable length, finally fall down into the mud, where they stick with their sharp point buried, and soon take root. Other seeds are furnished with wings that the winds may carry them far away; others, enveloped in water-proof shells, float on the surface of the sea, and are drifted by the currents to distant coasts; but here we have a tree whose seeds were destined to remain fixed on an uncertain soil, close to the parent plant, and surely this purpose could not have been fulfilled in a more beautiful manner.

Besides the elementary agencies of the winds and currents, nature has still other resources for conveying seeds to a distance from their place of growth. The various tribes of animals are busily engaged in furthering an object whence they themselves derive such important advantages. Sometimes an express provision is found in the structure of seeds to enable them to adhere firmly by prickles, hooks, and hairs, to the coats of animals or feathers of the winged tribe, to which they remain attached for weeks or even months, and are borne along into every region whither birds or quadrupeds may migrate. Few have failed to mark the locks of wool hanging on the thorn-bushes wherever the sheep pass, and it is probable that the wolf or lion never give chase to herbivorous animals without being unconsciously instrumental in the diffusion of plants. A deer has strayed from the herd, when browsing on some rich pasture, when he is suddenly alarmed by the approach of his foe. He instantly takes to flight, dashing through many a thicket, and swimming across many a river and lake. The seeds of the herbs and shrubs, which have adhered to his smoking flanks, are washed off again by the waters. The thorny spray is torn off, and fixes itself in his hairy coat, until brushed off again in other thickets and

copses. Even on the spot where the victim is devoured, many of the seeds which he had swallowed immediately before the chase may be left on the ground uninjured and ready to spring up in a new soil.

The passage, indeed, of undigested seeds through the stomachs of animals is one of the most efficient causes of the dissemination of plants. Thus, a flight of larks will fill the cleanest field with a great quantity of various kinds of plants, as the melilot, trefoil, and others, whose seeds are so heavy that the wind is not able to scatter them to any distance. Pulpy fruits serve quadrupeds and birds as food, while their seeds, often hard and indigestible, pass uninjured through the intestines, and are deposited far from their original place of growth, in a condition peculiary fit for vegetation. In this manner the Guava-tree, first introduced into the island of Tahiti about half a century ago, has been so copiously disseminated by the birds and cattle as to become the plague of the country. In their greedy attempts to monopolise the spice trade, the Dutch endeavoured to confine the Nutmeg-tree to the narrow precincts of Banda, by extirpating it on all other islands where it naturally grew; but their baseness was defeated by the wild pigeons, who, dropping the undigested nuts in their excursions over the Moluccas and neighbouring islands, continually showed them that man cannot possibly succeed when striving against the intentions of nature.

The sudden deaths to which great numbers of frugivorous birds are annually exposed must not be omitted, as auxiliary to the transportation of seeds to new habitations. When the ebbing sea withdraws from the shore, and leaves fruits and seeds on the beach or in the mud of estuaries, it might by the returning tide wash them away again, or destroy them by long immersions; but when they are gathered by land-birds which frequent the sea-side, or by waders and water-fowl, they are often borne inland; and if the bird to whose crop they have been consigned is killed, they may be left to grow up far from the sea. Let such an accident happen but once in a century, it will be sufficient to spread many of the plants from one continent to another; for in estimating the activity of these causes, we must not consider whether they act slowly in relation

to the period of our observation, but in reference to the duration of species in general.

Let us trace the operation of this cause in connexion with others. A tempestuous wind bears the seeds of a plant many miles through the air, and then delivers them to the ocean; the marine current drives them to a distant continent; by the fall of the tide they become the food of numerous birds, and one of these is seized by a hawk or eagle, which, soaring across hill and dale to a place of retreat, leaves, after devouring its prey, the unpalatable seeds to spring up and flourish in a new soil.

But no bird or four-footed animal is so instrumental in diffusing plants over the surface of the globe as man, that restless wanderer who claims the whole of it as his inheritance. He transports with him into every region the vegetables which he cultivates for his wants; through him the potato has been conveyed from the New World to Europe, and the Cinnamon-tree of Ceylon made to flourish in the Western Indies.

'When the introduction of cultivated plants is of recent date,' says De Candolle, 'there is no difficulty in tracing their origin; but when it is of high antiquity, we are often ignorant of the true country of the plants on which we feed. No one contests the American origin of the maize, nor the origin in the old world of the coffee-tree and of wheat. But there are certain objects of culture of very ancient date between the tropics, such, for example, as the banana, of which the origin cannot be verified. Armies, in modern times, have been known to carry in all directions grain and cultivated vegetables from one extremity of Europe to the other; and thus have shown us how, in more ancient times, the conquests of Alexander, the distant expeditions of the Romans, and afterwards the Crusades, may have transported many plants from one part of the world to the other.' But besides the plants used in agriculture, or introduced from foreign countries for the embellishment of our gardens, the number which have been naturalised by accident, or which man has spread unintentionally, is considerable.

'We have introduced everywhere,' observes De Candolle, 'some weeds which grow among our various kinds of wheat, and which have been received perhaps originally from Asia along with them. Thus, together with the Barbary wheat, the inhabitants of the south of Europe have sown, for many ages, the

plants of Algiers and Tunis. With the wools and cottons of the East, or of Barbary, there are often brought into France the grains of exotic plants, some of which naturalise themselves. Of this I will cite a striking example. There is, at the gate of Montpellier, a meadow set apart for drying foreign wool after it has been washed. There hardly passes a year without foreign plants being found naturalised in this drying-ground. I have gathered there *Centaurea parviflora*, *Psoralea palæstina*, and *Hypericum crispum*.' This fact is not only illustrative of the aid which man lends inadvertently to the propagation of plants, but it also demonstrates the multiplicity of seeds which are borne about in the woolly and hairy coats of wild animals. Many plants have been naturalised in our sea-ports by the ballast of ships, and others have spread through Europe from botanical gardens, so as to have become more common than many indigenous species. In the seventeenth century a ship from Japan was wrecked near Guernsey, and to this misfortune the beautiful Amaryllis owes its origin, which now serves to decorate the island.

It is scarcely two centuries since the Canadian Erigeron, or flea-bane, was brought from America to the Botanical Garden at Paris, and already the seeds have been carried by the winds over France, the British Islands, Italy, Sicily, Holland, and Germany.

The cereals, which we originally received from the distant East, have followed our colonists to America and Australia, but along with them the blue corn-flowers and scarlet poppies, the ornaments of our fields, have wandered to the prairies of Illinois, or to the plains of Victoria, where their well-known sight awakens many a fond recollection of former days in the heart of the emigrant. The plantain, or rib-wort, so common in our fields and meadows, follows everywhere the 'pale-faces' into the backwoods of America. Where the Indian sees this plant, he knows that he has not long to tarry in the land of his fathers, for the despoiling stranger is at hand.

Soon after the arrival of the Spaniards in Buenos Ayres, the thistle invaded the Pampas, as the immense grass-plains of that level country are called, and in course of time has covered many square miles with its prickly vegetation. In this congenial soil its growth is so luxurious as frequently to overtop

the rider on his horse, who is more at a loss to find his way through the impenetrable thicket than through the mazes of a primeval forest, as it prevents him from looking round, and affords him no solid stem on which he might climb to ascertain his position. Thus these thistle wildernesses, which owe their origin to the casual introduction, perhaps, of a single seed, have spread like a cancer over tracts of land larger than many a German principality, and have become one of the great nuisances of the country, as they not only usurp the place of useful grasses, but afford, moreover, a secure retreat to the jaguar, and to the still more dangerous banditti, who alone are acquainted with their labyrinthine paths.

When we consider the variety and efficacy of the means which Providence uses for the dispersion of plants, the lightness of many seeds, particularly of the lower cryptogamous plants, the feathery or wing-like appendages of others, the constant agency of the winds and currents, and the scarce less active interference of the birds, the four-footed animals, and man, we cannot wonder that, wherever vegetation can possibly exist, it should take possession of the naked soil. The process is more rapid in the humid countries of the tropical zone, more tardy under the chilling influence of the wintry north; but in course of time even the most desolate lava-fields, in the higher latitudes, hide their black waves of rugged stone under a more friendly garment, for which they are originally indebted to the seed-bearing winds.

First, lichens, mushrooms, mosses; then, such thrifty herbs as are content to feed upon nothing, have to prepare a scanty layer of mould or humus for the reception of more pretentious guests. Gradually some small stunted shrub makes its appearance here and there in some peculiarly favoured spot, and, after all, requires vast powers of endurance to maintain itself on the niggard soil, exposed to the perpetual enmity of wind and weather. This paves the way for a more vigorous and fortunate race; and as every year adds something to the vegetation on the mountain's side, and opposes increasing obstacles to the winds, the falling leaves and decaying herbage accumulate more and more, until dwarfish trees first find a sufficiency of soil to root upon, and finally the proud monarch of the forest spreads out his powerful arms, and raises his majestic summit to the skies.

CHAPTER XIII.

MICROSCOPICAL PLANTS.

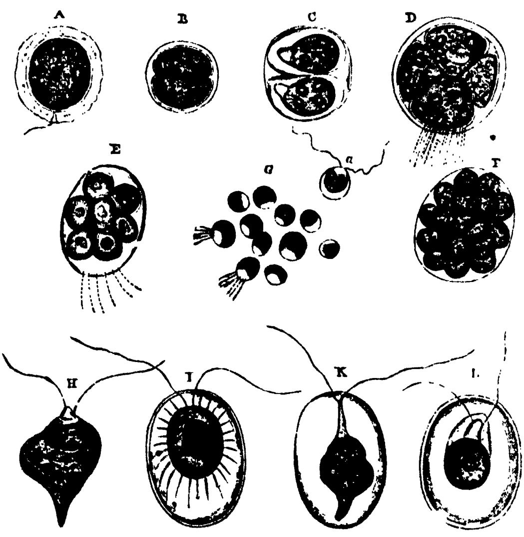
Uncertain Limits between the Animal and the Vegetable World.—The simplest Forms of Plants.—Protococci.—Oscillatoriæ.—Volvocinæ.—Desmidiæ.—Diatomaceæ.—Their Importance in the Household of the Seas.—Their Geological Agency.

THE limits between the vegetable and the animal world are by no means so strictly defined as might be supposed when merely considering the higher classes of both kingdoms. No one can possibly doubt the vegetable nature of the tree which he sees firmly rooted in the soil, or be inclined to reckon the swift-winged bird among the plants; but in the lowest and smallest forms of organic life, spontaneous motion ceases to be the distinctive character of animality. For the microscope has taught us not merely that the spores of the algæ, and many of the minutest plants, possess a power of spontaneous movement, but also that the instruments of motion, when these can be discovered, are of the very same character in the plant as in many of the lower animals, being little hair-like filaments, termed cilia (from the Latin *cilium*, an eyelash), by whose rhythmical vibrations the body of which they form a part is propelled in definite directions. The peculiar contractility of these cilia cannot be accounted for in either case, any better than in the other; all we can say is, that it seems, in all probability, to depend upon the continued vital activity of the living substance of which these filaments are prolongations, and that this contractile substance has a composition essentially the same in the plant as in the animal. Thus, in the present state of our knowledge, it is very difficult to lay down any definite line of demarcation between the two kingdoms; the only character which appears to establish a difference being that the simplest animals, like the highest members of their class, depend for nutriment upon

organic *compounds* already formed, which they take, in some way or other, into the *interior* of their body; while the lowest plants, in common with the highest, obtain their own alimentary matter by absorption from the *inorganic elements* (water, carbonic acid, ammonia, and various salts) on their exterior, and take in no solid particles of any description. Judged by this criterion (the only one which has any value in these days), the sponges, which were formerly supposed to be plants, have been definitively awarded to the animal kingdom; while many minute organisations, which once figured among the ranks of the *Protozoa*, or simplest animals, now find a more correct place among the *Protophyta*, or lowest members of the vegetable world.

A cursory glance at a few of the most remarkable of these minutest plants will give us some idea of the wonders evolved by the process of life in spaces so small as to be invisible to the naked eye, and show us that Divine power shines forth as brilliantly in the myriads with which it peoples a single drop of water as in the creation of worlds.

Among the simplest microscopical forms of vegetable life we



A Encysted 'still' cell of Protococcus. B C D E F Divisions of encysted cells into two, four, eight, and thirty-two. G Motile cells after their escape from the original cell. H I K L Transformations of motile cells.

find the *Protococci*, globular cells surrounded by a gelatinous envelope, and measuring scarce $\frac{1}{1000}$ of a line in diameter, which

frequently spread themselves as a green slime over the surface of ponds and ditches. Their multiplication by duplicate subdivision is so rapid that, in spite of their minuteness, extensive areas may be quickly covered, in circumstances favourable to their growth, by the products of one primordial cell.

But the most remarkable passage in the life-history of the Protococci is their alternation between a 'still' and a 'motile' condition. A 'still' cell, consisting of a colourless matter, through which green or red-coloured granules are more or less uniformly diffused, forms, by repeated self-divisions, 2, 4, 8, 16, 32 new cells or segments, which are of a very different nature from their inert parent, as they are provided with one or two cilia whose rhythmical contractions propel them rapidly through the water. For this reason they were formerly supposed to be animalcules, and made to figure in treatises on natural history as Monades, Astasiæ, Uvellæ, and under a variety of other names, each change of form resulting from the development of their growth being supposed to be a different genus of animal.

By the loss of their cilia, and the thickening of their envelope, the 'motile' cells pass into the 'still' form, and in this condition they may be completely dried up, and remain in a state of dormant vitality for many years. It is in this condition that they are wafted about in atmospheric currents; and being brought down by the rain into pools and cisterns, they may rapidly multiply and maintain themselves until the water is dried up, or any other unfavourable circumstance occurs which either kills them throughout or forces them to pass from the active into the dormant condition.

The cysts of the animalcules, precipitated conjointly with them by the rain, find, through their means, an abundant nourishment; and thus a little world of animals and plants appears, as if by magic, in the newly formed waters. When the ponds dry up, then the encysted and apparently lifeless animalcules, and the 'still' cells of the Protococci, rise on the wind into the atmospheric ocean, all ready for a new precipitation, and the peopling of some future pool.

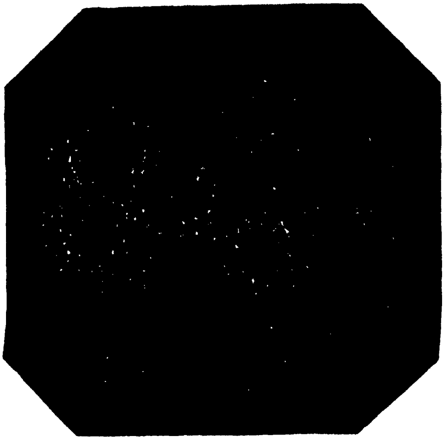
The *Oscillatoriæ,* another tribe of microscopical plants, consisting of continuous tubular filaments, formed by the elongation of their primordial cells, usually lying together in bundles or in strata, and sometimes invested by gelatinous sheaths, are

chiefly remarkable by the peculiar animal-like movements which they exhibit. If a piece of the stratum of an Oscillatoria be placed in a vessel of water, and allowed to remain there for some hours, its edge will first become fringed with filaments, radiating as from a central point, with their tips outwards. These filaments, by their constant oscillatory movements, are continually loosened from their hold on the stratum, cast into the water, and at the same time propelled forward; and as the oscillation continues after the filament has left its nest, the little swimmer gradually moves along, till it not only reaches the edge of the vessel, but often, as if in the attempt to escape confinement, continues its voyage up the sides, till it is stopped by dryness. *Thus in a very short time a small piece of Oscillatoria will spread itself over a large vessel of water.* This rhythmical movement, impelling the filaments in an undeviating onward movement, is evidently of a nature very different from the truly spontaneous movements of animals, and must be considered simply as the expression of certain vital changes taking place in the interior of the cells.

The Oscillatoriæ are commonly of some shade of green, but not unfrequently they are of a purplish hue, and sometimes so dark as, when in mass, to seem nearly black. They frequently form green scums on the surface of stagnant pools, but they also occur in salt waters, and sometimes in such incredible quantities that Professor Mayen once saw the ocean covered with them over a space of seven hundred miles. The water swarmed with small bodies of a stellar shape like snow flakes, which, on being examined through the microscope, were found to consist of bundles of Oscillatoriæ.

Among the marvels of microscopic vegetation, the *Volvox globator*, or 'globe animalcule,' as it has been called, from a false idea of its nature, holds a conspicuous rank on account both of the animalcule-like activity of its movements, and of the great beauty and regularity of its form. Attaining a diameter of $\frac{1}{30}$ of an inch, it may be seen with the naked eye, when the drop containing it is held up to the light, swimming through the water which it inhabits. Its onward motion is usually of a rolling kind, but it sometimes glides smoothly along without turning on its axis; whilst sometimes, again, it rotates like a top, without changing its position, so that it might

easily be mistaken for a single animal. But the microscope, the great revealer of hidden wonders, shows it to be of a far different and far more complicated nature, as no less than two or three thousand minute green spots or cells, often connected by green threads, and each enjoying its individual life, are here united to a hollow sphere. From each of *the spots proceed two long cilia, so that the entire surface is beset with these vibratile* filaments, to whose combined action its movements are due. Within the external sphere there may generally be seen from two to twenty other globes of darker colour, and of varying sizes. The smaller of these are attached to the inner surface of the investing sphere, and project from its cavity; but the larger lie freely within, and may often be observed to revolve by the agency of their own ciliary filaments. After a time the original sphere, too narrow to contain its growing progeny, is rent asunder, and the contained spherules, swimming forth and speedily developing themselves into the likeness of that within which they have been formed, in their turn give birth to new colonies, the parents of future generations.

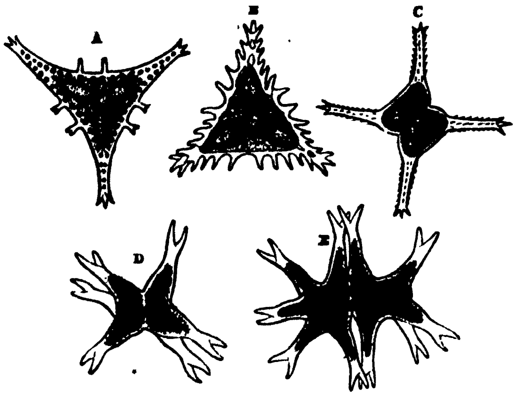


Volvox Globator (much magnified).

Such is the wonderful history of the Volvox, whose countless numbers frequently cover the surface of stagnant ponds and ditches to the depth of several feet, in multitudes so dense that the single spheres are hardly separated from each other by intervals of three or four times their own diameter.

Another highly interesting form of minute vegetable life is that of the *Desmidiaceæ*, simple cells generally independent of each other, but sometimes joined together in linear series by means of a gelatinous exsudation. The outer coat, which frequently possesses an almost horny consistence, but does not

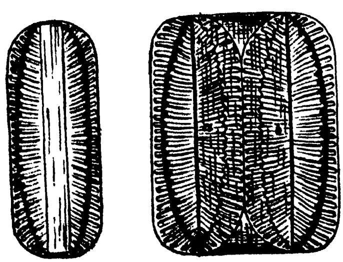
include any mineral ingredient in its composition, is generally divided by a sutural line into two equal halves, and often orna-



Desmidiaceæ.
A, Staurastrum vestitum; B, S. aculeatum; C, S. paradoxum; D, E, S. brachiatum.

mented with spinous projections, presenting a very symmetrical arrangement. These elegant little plants are fond of standing, though not stagnant, water. Small shallow pools, that do not dry up in summer, especially in open exposed situations, are their most congenial homes. The larger and heavier species commonly lie at the bottom, either spread out as a thin gelatinous substance, or collected into finger-like tufts. Other species form a greenish or dirty cloud upon the stems and leaves of other aquatic plants, where they serve as pasture-grounds for Infusoria and other microscopic animals.

The *Diatomaceæ* are likewise simple vegetable cells encased in a flinty envelope, consisting of two valves, usually of the most perfect symmetry, closely applied to each other like the valves of a mussel. The forms of these minute organisms are equally strange and beautiful, exhibiting mathematical figures, circles, triangles, and parallelograms, such as we find in no other plants, while their



surface is often most elaborately sculptured and dotted with

numerous apertures to admit the surrounding water into the internal cell. Many species are always met with entirely free, after the process of duplicative subdivision has once been completed; others remain adherent, forming stripes or bands or spirals, or even plant-like structures of exquisite delicacy and beauty, such as the Licmophora, or Fan-bearer, which is very common in April and May on the leaves of Algæ, and is very generally distributed round the British coasts, forming gelatinous masses of a clear brown colour on the plants it frequents.

The Diatomaceæ are found in fresh water streams and pools, but they chiefly abound in the ocean, no part of which is without its share of this ever-springing vegetation. Within the Atlantic circle, Dr. Hooker found them washed up in myriads by the sea on to the 'pack and bergs,' everywhere staining the ice and snow of a pale ochreous brown. Floating masses of ice when melted yielded them in countless millions, and the sounding-lead constantly brought them up from depths that would have engulphed Chimborazo.

The guano of the Chincha Islands contains innumerable shells of Diatomaceæ, which the birds, through whose intestinal canals they must have passed, drew forth with their prey out of the abounding water; and they are found in the dust which, wafted from the Sahara by the hot breath of the desert, frequently falls upon the decks of ships 300 miles from the African coast.

The indestructible nature of their flinty coverings has also served to perpetuate them from time immemorial. Man and all the higher animals pass away, and scarcely a vestige of their existence remains, but the Diatomaceæ build for eternity. Without cessation their remains are deposited upon the bottom of the sea; without cessation they are raising submarine banks, and filling up estuaries and channels. At first sight it may seem a gross exaggeration to attribute so vast an agency to beings so minute, but when we recollect how quickly they multiply by division, and how their activity dates from the first dawn of organic creation, their architectural powers no longer seem incredible. In forty-eight hours a single Diatomacea is able to multiply to eight millions, and in four days to one hundred and forty billions, when the silicious coverings of its enormous progeny would already suffice to fill up a space of two cubic feet;

no wonder then that, during the course of ages, these microscopic plants have been able to form prodigious strata wherever circumstances favoured their propagation.

Under the whole city of Richmond in Virginia, and far beyond its limits, over an area of unknown extent, they constitute a stratum of eighteen feet in thickness; and similar deposits are found in the Island of Mauritius, in the province of Oran in Algeria, in Bermuda, in the heaths of Luneburg in Hanover, and numberless other localities, so that there is scarce a country on earth where their fossil remains have not left the traces of their history in broad geological features. Nor are they of less importance in the great household of living creation. In the Antarctic Ocean, where there is a marked deficiency of higher forms of vegetation, they supply the chief food of the minor aquatic animals, which in their turn serve as prey to the fishes and Cetaceans. And not only in the vast deserts of the Polar Seas, but wherever they abundantly germ forth, under the stones of mountain-streams or in shallow pools, or in road-side ditches, they afford nourishment to an amazing multitude of small creatures. It is not useless that their propagation is so rapid, since enormous losses have constantly to be repaired, and not in vain that they abound in the most inhospitable seas, where but for them no sea bird would flap its wings and no dolphin dart through the desert waters.

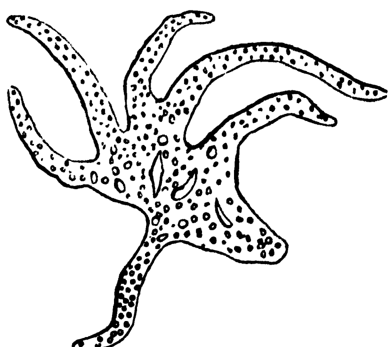
CHAPTER XIV.

MICROSCOPICAL PROTOZOA.

Rhizopods and Foraminifera—Their Geological Importance—Luminousness of the Sea—The Noctiluca miliaris—Polycystina—Infusoria—Vorticellæ—Ophrydinæ—Rapid Multiplications of the Infusoria.

THE first traces of animal life, such as they dawn forth in the Protozoa, are scarcely less interesting to the reflecting mind than the study of its highest and most developed forms. They are generally of a size so minute that the naked eye is either incapable of discerning them, or unable to distinguish their several parts; and one of the most splendid inventions of human ingenuity was necessary to make us acquainted with their existence. As the astronomer at every improvement of the telescope sees new worlds beam forth from yet more distant abysses of space, thus, as the microscope increases in power, new forms of hitherto invisible life reveal themselves to the zoologist in a drop of water, in the sand of the sea, or in the dust wafted together by the wind.

Armed with this marvellous instrument, he has as it were called forth an entirely new creation out of nothing, and discovered a little world of animated beings, where to his predecessors all seemed blank and void.

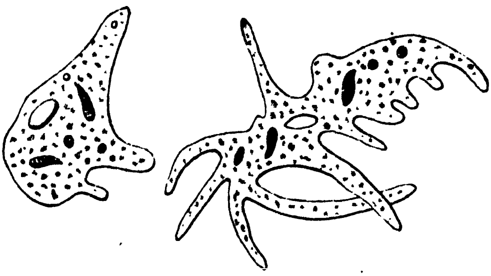


Amœba.

As far as science has hitherto ascertained, the *Rhizopods* occupy the lowest grade in the scale of these primitive beings. They are partly naked, partly enclosed in a shell, and owe their name to the filaments,

or feet, which they are constantly protruding either for locomotion or for the seizure of their food.

The naked Rhizopods consist of minute specks of a semi-fluid, jelly-like, but granular matter, which, when the animal is in a state of activity, are continually performing a circulatory movement. This substance, which has been termed 'sarcode' by the naturalists, is so plastic that the filaments protruded from the homogeneous mass, and again withdrawn into it, subdivide into finer and still finer threads, and are capable of blending with each other whenever they come into contact. Thus they are able to cast a perfect network round their prey, and to embed it in a living mucus until all its soluble parts have been absorbed. They have no stomach, no mouth, no muscles, no nerves, but each atom of their tiny composition is capable in turn of seizing, of digesting, and of moving.



Amœba.

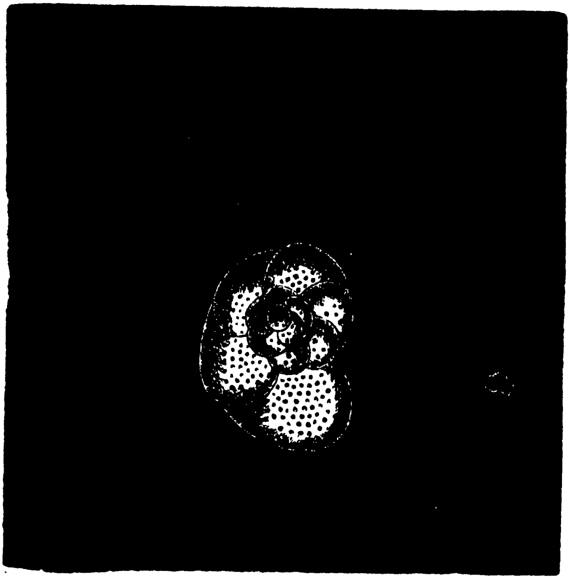
Showing the extemporaneous feet formed by evanescent projections of the general plastic mass of the animal.

Other creatures excite our wonder by their complicated structure, these by the excessive simplicity of their organisation.

Between the families of the naked Rhizopods and the shell-clad *Foraminifera* there are groups of intermediate types, which seemingly indicate the path of progress from the lower to the higher forms of these simple creatures. Sometimes the shell of the Foraminifera consists of only one chamber; in most cases, however, it contains a large number of cells, arranged in a vast variety of forms. Sometimes the little animal protrudes its filaments through a single aperture, sometimes through innumerable openings with which the shell is everywhere perforated; and when we consider that the diameter of these pores usually ranges from 1-3,000th to 1-10,000th of an inch, we can form some idea of the extreme delicacy of the foot-like threads to which they afford a passage.

The elegance of shape of the Foraminifera is no less remark-

able than their variety of form, which may well be called immense, as no less than 2,400 living and fossil species have



A Foraminiferi (Rotalia ornata) with its filaments extended.

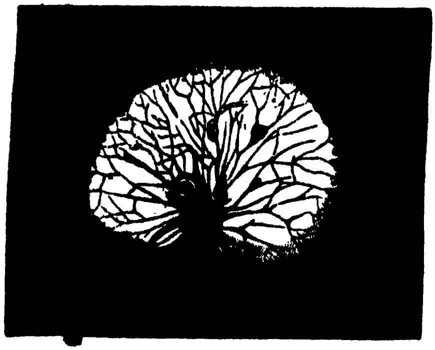
already been distinguished by naturalists. Here we see a group resembling exquisitely moulded flasks, or amphoræ, with beautifully fluted sides; there another alternately dilating and expanding like a string of chiselled beads; whilst others again exhibit the graceful spiral of the nautilus.

One of their most striking features is their marvellous minuteness. Janus Plancus, who first discovered them in the strand of Rimini, in the year 1731, counted about 6,000 of their shells in a single ounce of drift-sand; and Professor Schultze, of Bonn, found no less than a million and a half in the same quantity of pulverised quartz, from the shore of Mola di Gaeta. The Globigerinæ, which have been found in such vast numbers in the bed of the Atlantic, are each about 1-50th part of an inch in diameter, and the linear dimensions of recent British species are said by Professor Greene to vary from 1-5,000th to 1-50,000th of an inch! But the diminutive world of the Foraminifera has also its giants, particularly among the fossil species, such as the Nummulites, which occur in such

prodigious numbers in the limestone of the Egyptian pyramids, and whose flattened coin-like forms attain the comparative colossal diameter of from two to three inches. All the Foraminifera are aquatic. Some are found in sweet water, others attached *to sea-weeds or zoophytes, but by far the larger number in the* sand *or mud dredged up from the bottom of the sea.* Here *they frequently occur in such incalculable myriads as to form no less than half the bulk of the sand with which they are mixed.* Thus, along the whole Atlantic coast of the United States, the plummet constantly brings up masses of foraminiferous shells, so that this vast extent of ocean-bottom, which itself forms but a small part of the domains they occupy, is literally covered with their living legions or their tenantless exuviæ. And as the present ocean contains them in countless multitudes, thus have they swarmed in the waters of the primeval seas from the first dawn of creation, and piled up the monuments of their existence in vast strata of limestone. A great part of the rocky belt from Rügen to the Danish isles, the white chalk cliffs, which, beginning in England, extend through France as far as southern Spain; the limestone formations of Greece and Turkey, whose importance, as natural features of the country, is by some supposed to be indicated by the names of Creta and Albania, are chiefly formed of the shells of Foraminifera; and a zone of Nummulite limestone, frequently a thousand miles broad, and in many places of a prodigious depth, may be traced from the Atlantic shores of Europe and Africa, through Western Asia, up to North India and China. So important is the part which these beings, individually so minute, have performed and still perform in the geological annals of the globe.

The phosphorescence of the sea is one of the most charming phenomena that Nature in all her wide range of beauty offers to our admiring gaze. Who that has sojourned on the coast, or traversed the fields of ocean and witnessed it in its full splendour, can ever forget the deep impression made upon his mind when he first saw the dark waves curl over in flashing crests of light—when his vessel's bows ploughed up the waters in silvery furrows, or the rising flood broke in sheets of flame, or spangles of diamond brilliancy, on the glowing beach! Well may we be lost in wonder at so marvellous, so fairy-like a

spectacle—well may we be astonished at seeing the cold waters changed as it were by a magician's wand into cradles of fire! But our admiration increases when on enquiry into the causes of the gorgeous spectacle we learn that it is not the result of inanimate agencies, magnetic or electrical, but that it derives its origin from a living source, and that the *Noctiluca miliaris*, a globular gelatinous animalcule, nearly related to the Rhizopods, is the chief illuminator of the seas!



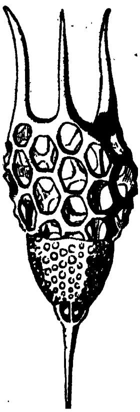
Noctiluca miliaris (much magnified).

This wonderful little creature is just large enough to be discerned by the naked eye when the water in which it may be swimming is contained in a glass jar exposed to the light; and a tail-like appendage marked with transverse rings, which serves as an instrument of locomotion, becomes apparent under a slight magnifying power. Near the point of its implantation in the body is a definite mouth leading into a large irregular cavity, apparently channelled out in the jelly-like substance of the body. The external coat is denser than the contained sarcode, and the former sends thread-like prolongations through the latter, so as to divide the entire body into irregular chambers. 'The nature of its luminosity,' says Dr. Carpenter, 'is found by microscopic examination to be very peculiar, for what appears to the eye to be a uniform glow, is resolvable under a sufficient magnifying power into a multitude of evanescent scintillations; and these are given forth with increased intensity whenever the body of the animal receives any mechanical shock.'

To fill up the length of an inch it would require 170 Noctilucæ ranged in a line, and millions could be contained in a wine-glass. And yet in every zone they make the wide surface of the nocturnal ocean glow and sparkle with an elfish light.

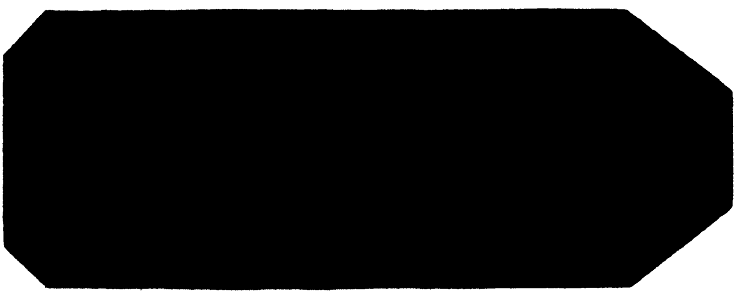
Among the microscopic wonders of the ocean, the *Polycystina*,

first discovered by Professor Ehrenberg, at Cuxhaven, on the North Sea, occupy a conspicuous rank, both by their numbers and their beauty and variety of form. The sarcode body of these minute siliceous shells extends itself like that of the Foraminifera into foot-like prolongations, which pass through the larger apertures by which they are perforated. It is a peculiar feature of these elegant shells (whose delicate sculpture frequently reminds the observer of the finest specimens of the hollow ivory balls carved by the Chinese), that they are usually surmounted by a number of spine-like projections, very frequently having a radiate disposition. Some have an oblong shape, others a discoid form, from the circumference of which the siliceous spines project at regular intervals, so as to give them a star-like aspect. They are generally of smaller size than even the Foraminifera, and appear to be almost as widely diffused, *as they have been brought up by the sounding-lead from the bottom of the Atlantic and from the abysses of the Antarctic seas.*



Polycystina

They also have largely contributed to the structure of the earth-mud; their siliceous deposits abound in the marls of Sicily and Greece, and a large proportion of the rock that prevails through an extensive district of the island of Barbadoes is chiefly composed of their remains.



Stentor Rœselii (highly magnified).

The *Infusoria*, which owe their name to the circumstance of their having been first discovered in artificial infusions of organic

substances, occupy the highest rank in the Protozoic world. They are all exceedingly minute, but of various dimensions; the greater number being individually invisible to the naked eye, while some, like the Stentor, attain the comparatively large size of 1-30th of an inch. This beautiful creature resembles a gelatinous trumpet, and is flexible and contractile in all directions, either while swimming about freely in the water, or while attached, as it frequently is, to some foreign body by means of a little sucking-disk which terminates the pointed extremity of the tail.

The various species of Infusoria exhibit a great diversity of form—globular, oval, cylindrical, thread-like. Most of them are free in their movements, some permanently attached to stalks; by far the greater number are colourless and transparent, while some have a yellowish, greenish, or reddish tinge. Compared with the Protozoic families already described, their higher organic development is *chiefly exhibited by their possession of a mouth and rudimentary digestive organ*, while well-marked cilia or hair-like appendages, disposed either along the entire margin of the body, as well as around the oval aperture, or limited to the immediate vicinity of the mouth, serve them as instruments of prey and locomotion. During the life of the animal these cilia are in almost constant action, their motion consisting of bends in rapid succession from base to point, and of an immediate return to the original position, not unlike the undulating motion of a cornfield under the influence of the wind.

Various Forms of Infusoria.
1, 2. Coleps hirtus. 3, 4. Trachelius anas. 5. Trachelius ovum.
o, mouth; *a*, outlet of alimentary canal.

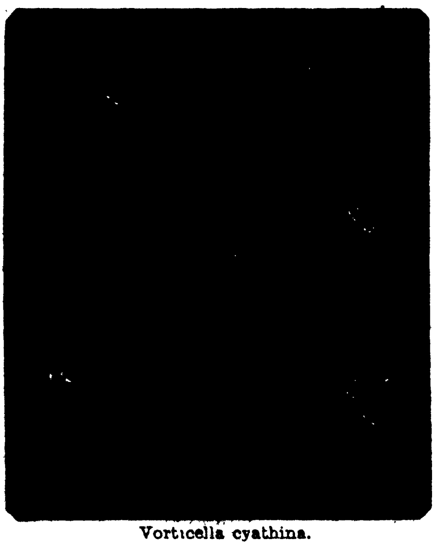
Thus currents or vortices are produced which enable their tiny possessors to ingulf the still more tiny prey that comes within reach of their irresistible whirlpools. The exceeding minuteness, as well as the rapid movements of the cilia, often make it difficult to observe them, though, when invisible, their existence

may be frequently inferred from the agitation of minute particles in the currents they produce. Simple as these organs are, they harmonise beautifully with the wants of the little creatures to whom they have been given; they are useful as oars, as arms, as tentacles; they hurry along the food without further trouble to the mouth; they serve also for respiration, by bringing successive portions of water into contact with the surface of the animal, and are indeed no less admirable in their way than the elephant's proboscis or the chameleon's tongue.

Sometimes instead of a multitude of short cilia, as, for instance, in *Leucophrys patula*, we find a small number of long slender filaments, usually proceeding from the vicinity of the mouth, while in other cases the filaments are comparatively short, and have a bristle-like firmness, and instead of being kept in vibration they are moved by the contraction of the substance to which their bases are attached, in such a manner that the animalcule crawls by their means over a solid surface.

Leucophrys patula.

Thus in this little world of animalcules, which still contains so many unravelled secrets, we find almost all the modes of movement of the higher aquatic animals—the darting of the fish, the hop of the Daphnia, the gyrations of the water-beetle, and the tardy creeping of the leech.

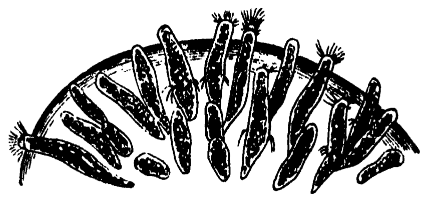


Vorticella cyathina.
b, c, d, e, f, exhibit the various steps of fissiparous reproduction in this animalcule

The bell-shaped Vorticella, one of the largest, is also one of the most beautiful and interesting of the Infusoria. In its first youth it swims freely about in the stagnant waters, but at a later period it attaches itself by a long stalk (g) to the leaves of duck-weed or the carapaces or shells of water-fleas or lacustrine snails, where

it frequently presents the appearance of a group of exquisite microscopic flowers. The rim of the vase-like body is tipped with a spiral of cilia, one end of the circling row descending a short distance down the side of the vase to a point where the oral aperture of the creature is placed. When the Vorticella is in search of food with its cilia in active vibration, the stalk is fully extended, but at the slightest disturbance it shrinks into close spiral folds so as to draw the little bell as far as possible from danger.

The Ophrydinæ, another family of Infusoria, are remarkable for their being usually found embedded in a gelatinous mass of greenish colour, which is sometimes adherent, sometimes free, and may attain the diameter of four or five inches, presenting such a strong general resemblance to a mass of frog's spawn as to have been mistaken for such. From a comparison of the dimensions of the individual Ophrydia, each of which is about $\frac{1}{120}$ of an inch in length, with those of the composite masses, some estimate may be formed of the number included in the latter, for a cubic inch would contain nearly eight millions of them; and many times that number must exist in the larger masses, even making allowance for the gelatinous cushion which envelopes the individual animalcule.



Section of a portion of the periphery of Ophrydium versatile.

showing the manner in which the individual animalcules are implanted in the mass.

In the water all these congregated animalcules are disposed in close rows, something in the same manner as in Volvox. On shaking the mass, many others show themselves within, between the former, so as to form from three to five different ranks. At first all the gelatinous cells appear to be connected with the centre of the mass by filamentary prolongations, but these disappear as they proceed internally, so that the middle of these wonderful animated little globes seems to be hollow and full of water.

The Infusoria are almost exclusively aquatic; most of them live in ponds, morasses, pools, wells, or cisterns; many are marine, but a few are found both in sweet and salt water. Some

exist in moist earth, others lead a parasitic life, not only in the stomach of frogs and earth-worms but even in the body of other Infusoria.

Of all animals they enjoy the widest range of habitation, and several of them may well be called cosmopolites, as they have been found in the Arctic and Antarctic seas, on the coasts, and far away on the ocean, on high mountains, and deep in the mines of Freiberg in Saxony.

Their reproduction is effected sometimes by eggs or by budding, but generally by spontaneous division, either longitudinally or in a transverse direction, and as this operation is capable of being repeated every six or eight hours, we can easily comprehend how the surface of clear stagnant waters may in a short time be covered with a green mass consisting of billions of Infusoria. When we consider that these minute forms of life most probably witnessed the dawn of animal creation, our imagination can form no idea of the number of generations that must have succeeded each other from their first appearance on earth to the present day; but as only a few of these are enclosed in a solid shell, their geological importance is far inferior to that of the calcareous Foraminifera or of the flint-cased Diatomaceæ and Desmidiaceæ.

One of the most wonderful passages in the life history of the Infusoria is the encysting process which at certain times they undergo, and which serves to preserve them under circumstances which do not permit the continuance of their ordinary vital activity. Previously to the formation of the cyst, the movements of the animal diminish in vigour and gradually cease altogether; its form becomes more rounded; its oral aperture closes, and its cilia are either lost or retracted. The surface of the body then exudes a gelatinous excretion which hardens around it so as to form a complete coffin-like case in which the torpid animal remains embedded until the fostering influences of warmth and humidity again recall it to an active life.

Incalculable numbers of these encysted Infusoria are constantly wafted about in the atmosphere or carried by the winds from land to land; and thus we can readily comprehend how pure watery infusions, when exposed to the air, soon begin to swarm with a little world of the minutest animals and plants.

The ubiquity and perfectly astounding numbers of the

Protozoa are sufficient proofs of their vast importance in the household of nature. Along with the Diatoms, the Desmidias, and other microscopical forms of vegetation on which their own existence depends, they evidently constitute the bases on which the superstructure of all the higher orders of animal life reposes. Hosts of Rotiferæ, minute Crustaceans, Annelides and Acalephæ, feed upon their inexhaustible legions, and serve in their turn to sustain animals of a larger and still larger size, until finally Man is enabled to feast on the teeming abundance of the lakes, the rivers, and the seas.

CHAPTER XV.

SPONGES.

Their Animal Nature—Their remarkable Structure—Their Skeleton—Spicula—Sensibility and Spontaneous Movements—Their Mode of Propagation—Their Importance in the Household of the Seas.

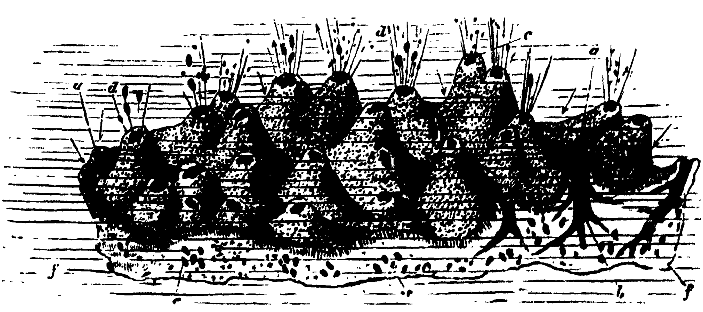
The Sponges, which were formerly supposed to belong to the world of plants, have been proved by modern researches to form a peculiar group of Protozoa. Attached to a solid base, they revel like the polyps in every variety of shape and tint, imitate like them every form of vegetation, and adorn like them the submarine grounds with their fantastic shrubberies. More than sixty different species have been discovered in the British waters alone, and as they go on, increasing in number and beauty until they attain their highest development along the shores of the Tropical Ocean, they no doubt hold a conspicuous rank among the living wonders of the sea.

Portion of a Sponge (Halichondria) with spicules projecting from the fibrous network.

The first object that strikes us in their organisation is *their skeleton, which is usually* composed of an irregular network of tough horny fibres, so arranged as to form a complex aggregation of canals, the flexibility of the fibres differing in different species of sponge. Generally this fibrous mass is interwoven with numerous mineral spicules, which serve to strengthen the fabric and in some species entirely replace the horny fibre, though they are still so arranged as to preserve the reticulated

character. These spicules are of a wonderful variety and elegance of form, for their shapes are not only strictly determinate for each species of sponge, but each part of the sponge, it is believed, has spicula of a character peculiar to itself. Sometimes they are pointed at both ends, sometimes at one only, or one or both ends may be furnished with a head like that of a pin, or may carry three or more diverging points, which sometimes curve back so as to form hooks. Sometimes they are triradiate, sometimes stellar, in some cases smooth, in others beset with smaller spinous projections like the lance of the saw-fish. As they are generally composed of flint, it may well be imagined that our household sponge entirely owes its value to their absence in its highly flexible structure. The sponge-skeleton is covered externally and along the internal surfaces of the canals with a gelatinous or slimy substance, similar to that which constitutes the body of the Rhizopod, and which, seemingly inert and unorganised, is yet the seat of whatever life the sponge contains. It is by this slime, which may be pressed out with the finger, that the net-work is deposited, and from it the whole growth of the mass proceeds.

On examining a sponge, the holes with which the substance is everywhere pierced may be seen to be of two kinds: one of larger size than the rest, few in number, and opening into wide channels and tunnels which pierce the sponge through



Halina papillaris.
Currents passing inwards through the pores (*a.a*), traversing the internal canals (*b*), and escaping by the larger vents (*c.d*).

its centre; the other minute, extremely numerous, covering the wide surface, and communicating with the innumerable branching passages which make up the body of the skeleton.

Through the smaller openings or pores the circumambient water freely enters the body of the sponge, passes through the smaller canals, and ultimately reaching the larger set of vessels, is evolved through the larger apertures or oscula. Thus by a still mysterious agency (for the presence of cilia has as yet been detected but in one genus of full-grown marine sponges), a constant circulation is kept up, providing the sponge with nourishing particles and oxygen, and enabling its system of channels to perform the functions both of an alimentary tube and a respiratory apparatus.

Dr. Grant describes in glowing terms his first discovery of this highly interesting phenomenon. 'Having put a small branch of sponge with some sea-water into a watch-glass, in order to examine it with the microscope, and bringing one of the apertures on the side of the sponge fully into view, I beheld for the first time the spectacle of this living fountain vomiting forth from a circular cavity an impetuous torrent of liquid matter, and hurling along, in rapid succession, opaque masses, which it strewed everywhere around. The beauty and novelty of such a scene in the animal kingdom long arrested my attention, but after twenty-five minutes of constant observation, I was obliged to withdraw my eye from fatigue, without having seen the torrent for one instant change its direction, or diminish in the slightest degree the rapidity of its course.'

Subsequent observations have proved that the living sponge has the power of opening and closing at pleasure its oscula, which are capable of acting independently of each other, thus fully establishing the animal nature of these simple organisations, in whom latterly even traces of sensibility have been detected, such as one would hardly expect to meet with in a sponge. For these creatures, as we are entitled to call them, are able to protrude from their oscula the gelatinous membrane which clothes their channels, and on touching these protruded parts with a needle, they were seen by Mr. Gosse to shrink immediately,—a proof that the sponge, however low it may rank in the animal world, is yet far from being so totally inert or lifeless as was formerly imagined.

The propagation of the sponges is provided for in a no less wonderful manner than their respiration and nourishment. Their young eggs or sporules germinate on the sides of the

canals, forming innumerable minute bud-like points. These, as they increase in size, are gradually clothed with vibratile cilia, and finally detaching themselves are cast out through the oscula into the world of waters. Here their wanderings continue for a short time, until, if they be not devoured on the way, they reach some rock or submarine body, on which, tired of their brief erratic existence, they fix themselves for ever, and bidding adieu to all further rambles, lead henceforth the quiet sedentary life of their parents.

In this manner the sponges, which otherwise would have been confined to narrow limits, spread like a living carpet over the bottom of the seas, and in spite of their being utterly defenceless maintain their existence from age to age. At the same time they serve to feed a vast number of other marine animals, for the waters frequently swarm with their eggs, and these afford many a welcome repast to myriads of sessile shells, worms, polyps, and other creatures small or abstemious enough to be satisfied with feasting on atoms.

CHAPTER XVI.

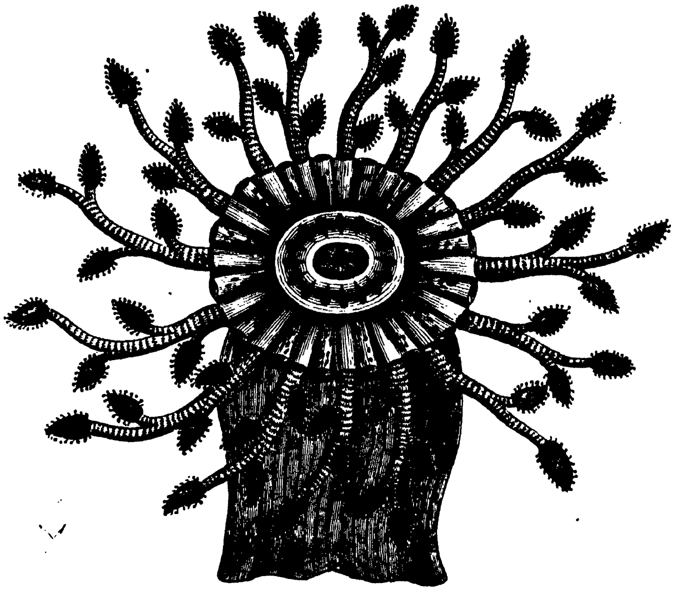
SEA-ANEMONES AND LITHOPHYTES.

Submarine Gardens.—Internal Structure of the Sea-anemones.—Tentacles.—Urticating Organs.—Their Remarkable Tenacity of Life.—Their Modes of Locomotion.—Lithophytes.—Social Republicans.—Coral-islands.

WHO has ever sojourned on a rocky coast, worn and hollowed by the breakers of a thousand years, without admiring the crystal tide-pools, those charming relics of the receding flood, so full of all that can fascinate the naturalist, or enchant the poet. For the calm and transparent waters of these miniature lakes harbour a little world of animals and plants of such wonderful variety and elegance of form that the eye never tires of gazing on their loveliness, and the memory reckons them ever after among the chief beauties of the beautiful ocean. There, bathed in liquid crystal, delicate sea-weeds spread their graceful fronds, or clothe the naked rock with a velvet carpet; there annelides, and crustaceans, and molluscs of all forms and colours, reposing, wandering, darting, creeping, or swimming, enliven the ever-changing scene, and there, not the least ornament of these fairy gardens, the radiate Sea-anemones, emulating the daisies of the fields, expand their lustrous disks.

Desirous of plucking one of these elegant flowers of the ocean, you extend your hand, but at the slightest touch its beautiful coronet begins to curl and pucker its margin, and to incurve it in the form of a cup. If further annoyed, the rim of this cup contracts more and more, until the animated blossom, now transformed into a shrivelled shapeless mass, and receding all the time from the rude assault, retires under the cover of its rocky fortress, or clings with such tenacity to the stone to which it is attached that you will sooner tear it to pieces than make it forego its grasp.

This wonderful daisy of the waters, this flower-like creature, which thus evidently reveals its true animal nature, is disseminated over the ocean in numerous genera and species, forming one of the families of the wide-spread class of the polyps. In all the Sea-anemones we find an oval or oblong

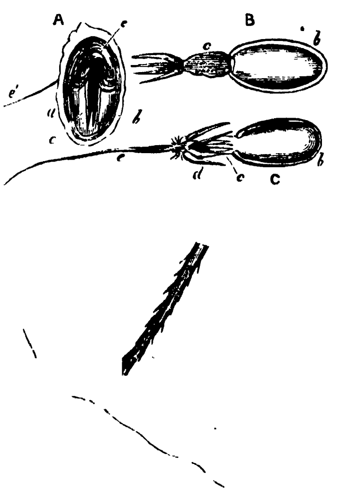


Actinia Alcyonoidea.

mouth, leading into a sack-like stomachal cavity, and surrounded by a crown of tentacles, sometimes resembling a Gorgon's head of long thick worms clothed in satin and velvet, and sometimes forming a dense thicket of slender filaments. The colours of these wonderful organs are as various as their dimensions—scarlet, green, azure, orange, or milk-white,—but their beauty only appears when in the expanded state, for the contracted sea-anemone is grey or brown like the stone to which it clings. Veiling its beauty under this homely disguise, it no doubt escapes many dangers, and the sand and shell-fragments that frequently remain attached to its viscid body still further help to screen it from its enemies. Its flowery disk spreading over a carpet of algæ, the Actinia, seemingly as insensible as the surrounding sea-weeds, might well be taken for the image of harmless innocence; but woe to the nimble cyclops, or to the wandering annelide,

that comes within its reach, for, seized by its irresistible arms, it is soon conveyed to the gaping mouth, ever ready to ingulf it in a living tomb. Yet it is not by brute force alone that the rapacious polyp thus overpowers its prey, but by means of those remarkable 'thread, or urticating cells' which have been given to many others of the humbler submarine animals, but chiefly to the polyps and acalephæ, and, like the stings of the nettle or the poison-fangs of the viper, not only wound but paralyse resistance by a venomous secretion.

These urticating organs, which are disseminated in multitudes over the tips of the tentacles, are composed of a delicate membranous sac (*a*), enclosing a much thicker one (*b*), which is open at one extremity, the aperture being stopped by the end of a more or less irregular short stiff sheath (*c*) sometimes giving attachment to several distinct rays or spines (*d*) applied together, which is fixed to the edges of the aperture, and occupies the axis of the inner sac. To the extremity of this sheath a long frequently toothed filament (*e*) is attached, and lies coiled up round the central sheath, and in close contact with the walls



of the sac. The latter are very elastic, and seem to be tensely stretched by the contained fluid during life, for on pressure the sac suddenly bursts, and its contents are evacuated so rapidly as hardly to allow of the process being traced. The violent protusion of the serrated filament, accompanied by an acrid secretion, causes many a worm or crustacean of equal or superior strength, that might have gone forth as victor from the struggle for life, to succumb to the insidious Actinia, and is even in many cases exceedingly irritating to the human skin. Besides enabling its possessor to derive his subsistence from animals whose activity, as compared with his own, might be supposed to have removed them altogether out of the reach of danger, these stings

serve also as admirable weapons of defence, and many a rapacious Eolide that would willingly have feasted upon a Sea-anemone is repelled by the acrid properties of its urticating tentacles.

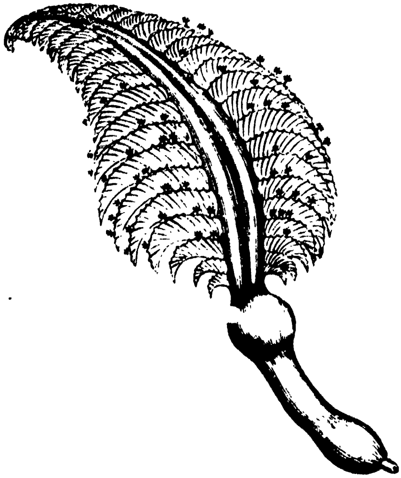
But even when in the power of an enemy, who does not fear the poison of its sting, the Sea-anemone frequently owes its preservation to its uncommon tenacity of life. Dip it into water warm enough to raise blisters on the skin, or expose it to the frost of winter, or place it under the exhausted bell of an air-pump, and its powerful vital principle will triumph over all these ordeals. Cut off the tentacles, and new ones sprout forth; nay, divide the animal in two, and, like the Lernæan hydra, it will produce a reduplication of itself. Possessing such wonderful powers of reproduction, the Sea-anemone may thus be cruelly maimed or torn by tooth or claw, and yet repair its losses and survive.

When desirous to wander, the Sea-anemones have several modes of locomotion. Relaxing the tenacious grasp of their muscular stalk, they glide slowly along; or, turning themselves upside down, they make use of their tentacles as feet; or, inflating their body with water, they diminish its specific weight, and allow themselves to be drifted along by the current, until, tired of exercise, they again fix themselves to some convenient spot.

The Actinias can neither hear nor see, for, as they are capable of but slow progression, the possession of the higher senses would have been of no use to avoid pursuit, or to capture a prey which the sea brings to their mouth without the least exertion on their part; it would have been a torment, not a gift. The sense of touch, which is principally concentrated in their tentacles, is amply sufficient for the limited sphere of their existence; and thus the organisation of the Actinia is as perfect in its way as that of any of the higher animals, for each part and each faculty harmonises with the whole, nor can we doubt that, where this harmony exists, even the humblest life has its share of enjoyment.

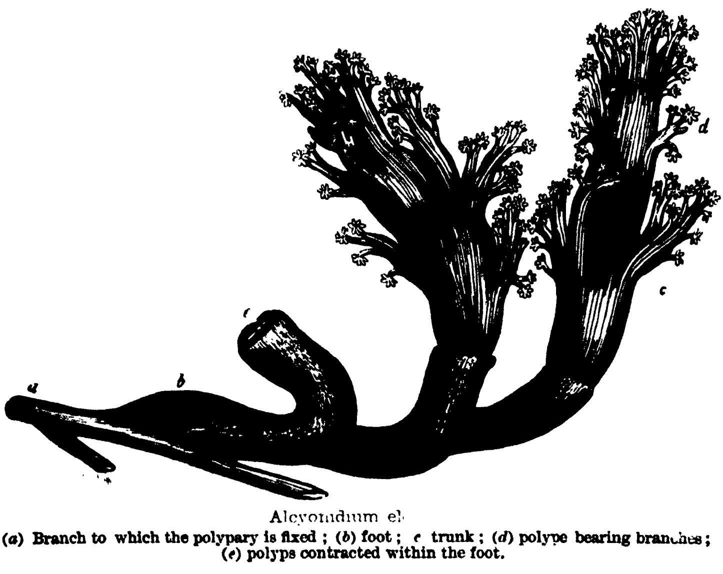
In spite of their numbers and their wide dispersion over the seas, the simple or solitary Actinias form but a small part of the world of polyps, which chiefly consist of aggregated or compound animals, attached to one another by lateral appendages, or by their posterior extremity, and participating in a common life, while at the same time each member of the family enjoys its independent and individual existence. But few of

these compound polyps are at liberty to swim about in the sea, as for instance the Pennatulæ, or Sea Pens; but few, like the Alcyonians, are of a spongy or cork-like nature, covering submarine bodies with shapeless masses. The majority, like the Red Coral of the Mediterranean, consist of a living and soft rind, enveloping a solid calcareous axis, or, like the reef-building Lithophytes of the tropical seas, form populous colonies inhabiting cells, distributed over the surface of stony polyparies.



Pennatula Grisea.

The individual animals of these social republics are far inferior in size to the Sea-anemone, but their communities



Alcyonidium el

(*a*) Branch to which the polypary is fixed; (*b*) foot; *c* trunk; (*d*) polype bearing branches; (*e*) polyps contracted within the foot.

frequently occupy a much larger space, so as to attain a diameter or height of many feet. Like the plants which they frequently

resemble in outward appearance, these stone-corals grow by germination, so that each polypary consists of a series of generations, constantly increasing and multiplying without ever separating from the parent stock. A necessary consequence of this mode of propagation is the intimate union of all the members of these vast communities. Each polyp has its own

Red Coral (Gorgonia Nobilis). A small detached portion magnified.

tentacles, mouth, and stomach; each is capable of shrinking within its cell, or of seizing its prey; but here its individuality ceases, as it communicates by membranes and vessels with its neighbours, and the juices which it elaborates are made to contribute to the nutrition of the whole community.

Thus we see in these humble associations the realisation of an Utopian republic, in which all the citizens have their equal share of the common property, and all equally labour for the

welfare of the state. Linked together by an indissoluble chain, *five millions* of individuals live together in peace and harmony in one single porite of ten feet diameter—a condition of tranquillity and ease which, no doubt, would soon give way to the utmost anarchy if the tiny republicans were suddenly endowed with human power of locomotion and human passions.

Only the outer rind or superficial structure of the larger corals is alive, for as the progress of growth piles new generations and new layers of chalk over their heads, the older polyps, cut off from the sources of supply, and suffocated, as it were, by their children, inevitably perish. But the skeleton, which they secreted during life, remains as an indestructible record of their existence, for while, with rare exceptions, the bones of the higher animals vanish after a few years from the surface of the earth, leaving no trace behind, the stone polyp, firmly rooted to the spot which it occupied while alive, mocks the lapse of centuries, and seems to bid defiance to all time. The coral-reefs of the primitive world form a conspicuous portion of the earth-rind, and as they are frequently situated in the depths of continents, or beyond the limits of the polar circle, lead us back to times when the tides broke against the mountains of Switzerland, or the shores of Spitzbergen were washed by a tepid sea.

The most ancient monuments erected by man to mark his transient passage on earth—the pyramids of Egypt or the temples of Meroë—do not reach perhaps beyond fifty or sixty centuries; but here we have ramparts, to which the great wall of China is a pigmy, erected at periods separated from the present times by an incalculable series of ages.

On submarine cliffs in the warmer seas, where the temperature of the water never sinks below 60° Fahr., the reef-building corals rear their wonderful palaces of stone. The depth to which they can live does not exceed twenty or thirty fathoms; but as large areas of the sea-bottom on which they grow are gradually subsiding, while their growth is at the same time constantly tending upwards to the level of the lowest ebb, their structures may in many places rise from vertical depths of many hundred feet. The coral-reefs thus raised in the course of ages by these minute and individually so puny architects are frequently of truly colossal dimensions, stretch for hundreds of miles along the coasts, fringe or encircle whole islands or

groups of islands, or form immense rings or annular break-waters round an interior lake originally occupied by land, which the gradual subsidence of the bottom has long since whelmed under the waters.

As living coral-reefs do not grow above low-water mark, it may well be asked how habitable islands, of which there are a large number dispersed over the Pacific and Indian seas, can form upon their crests. The breakers are here the agents of construction. They rend fragments and blocks from the outer border of the reef, and throw them upon the surface, corals and shells being pulverised by their crushing grinding power, and gradually consolidated into a compact mass. In this manner the pile rises higher and higher, till at last even the spring tides can no longer wash over it into the tranquil lagoon on the border of which the fine coral-sand accumulates undisturbed. The seeds which the ocean-currents carry with them from distant continents find here a congenial soil, and begin to deck the white chalk with an emerald carpet. Trees drifting from the primeval forest, where they have been uprooted by the swelling of the river on whose banks they grew, are also conveyed by the same agency to the coral shore, and bring along with them small animals—insects or lizards—as its first inhabitants.

Before the screw-pine raises its streaming tufts, or the stately palm waves its broad feathery fronds, sea-birds assemble on this new resting-place, and land-birds, driven by storms from their usual haunts, enjoy the shade of the rising shrubbery. At last, after vegetation has completed its work, man appears on the scene, and calls himself the sovereign of this little world.

Thus these wonderful coral-islands, with their plants and animals, are the product of numerous agencies acting independently of each other, and yet all directed to one common end. The peculiar organisation of the reef-building polyps, the heaving force of the breakers, the ocean-currents conveying seeds and germs from vast distances over the surface of the sea, the peculiar formation of the fruits of the cocoa and the screw-pine, which enables them to remain steeped for a long time in salt water and to perform immense sea voyages without losing their germinating power,—all were necessary either to raise

the coral-islands above the level of the waters, or to transform them from naked cliffs into tropical gardens. Here surely blind chance has not been at work, but the ineffable wisdom of an Almighty God.

If these gems of the ocean required but a few hours for their formation, if we could see them suddenly emerge from the waves, and the white rocks rapidly cover themselves with verdure, and the colonies of sea-birds hasten to their new homes, and man erect his dwellings on these magic isles,—then indeed our astonishment would know no bounds, and we should look down with pity upon him who would attribute them to a fortuitous concurrence of physical causes: but are the coral-islands less wonderful, or do they less clearly proclaim the glory of their Maker, because centuries on centuries were necessary to raise and to adorn them?

CHAPTER XVII.

ACALEPHÆ OR JELLY-FISHES.

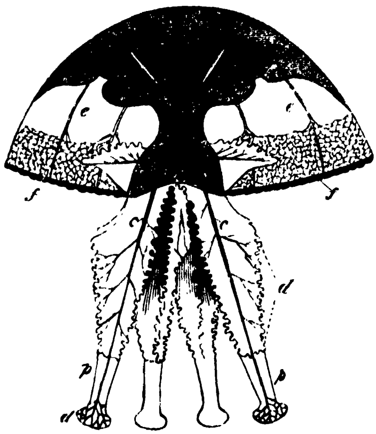
Medusæ and Rhizostomata.—Their Internal Structure.—Their Mode of Progression.—Alternation of Generations.—Ciliograde Jelly-fishes.—Their wonderful Fishing Apparatus.—Diphyes.—Agalma.—Physalus.—Velella.—Importance of the Acalephæ in the Economy of the Ocean.

NOT less admirable than the coral-myriads which pave the bottom of the ocean with petrified gardens and animated flower-beds, are the soft crystalline hosts of the Acalephæ or Jelly-fishes, whose incredible numbers excite the astonishment of the mariner when for days together he steers through their innumerable shoals. The variety and singularity of their forms, the brilliancy of colour which makes many of them true gems of the ocean, their remarkable structure and wonderful transformations, all contribute to delight the spectator, and to raise the interest of the naturalist.

When walking on the beach we chance to see a Jelly-fish abandoned by the retreating flood, we can hardly imagine how this disgusting gelatinous mass can ever have had claims to beauty; but this collapsed and formless wreck was elegant and handsome while it moved along in its own native element, and its organisation shows no less the wisdom of the Creator than the more complex though not more perfect structure of the higher stages of animal existence.

A soft gelatinous transparent or translucent body, without a calcareous skeleton or intestinal duct, and whose parts, divisible by four, are mostly ranged in a radiate manner round a centre, is the common character of all the Acalephæ; but their chief divisions or groups—bell-shaped, ribbed, or tubular—show such remarkable differences in their external forms and internal structures that it is hardly possible to comprise them in one

description. The Discophora are distinguished by a watch-glass or bell-shaped body, generally pellucid, from the lower surface of which various processes and filaments depend; but there are very many modifications in the structure of the various species. The Medusæ, for instance, are provided with a large central mouth, leading directly into the stomach, and surrounded by four brachial appendages, while numerous slender fibres or tentacula hang from the border of the umbrella-shaped disk. The Rhizostomata, on the other hand, have no tentacles round the margin of the disk, but are furnished with eight arms in the centre proceeding from a common stalk, and instead of a central oral opening, we find here each arm traversed by channels (*c*), leading to the digestive cavity (*a*), and dividing into numerous branches with narrow openings at the lower extremity (*d*). Through these minute apertures nourishment is received, which consequently must consist of very small animals indeed. On injecting milk into the oral cavity of the Discophora, vessels symmetrically arranged in a radiate manner, and divisible by four, become apparent, which, proceeding to the margin of the disk, there terminate in a circular vessel, which is supposed to be a respiratory organ. Small reddish or brownish eyes and tiny vesicles containing a limpid fluid and chalky otolithes arranged along the margin of the disk, communicate the impressions of light and sound, and the sudden retraction of their tentacles when seizing their prey sufficiently proves them to be possessed of a high degree of sensitiveness.



Rhizostoma.

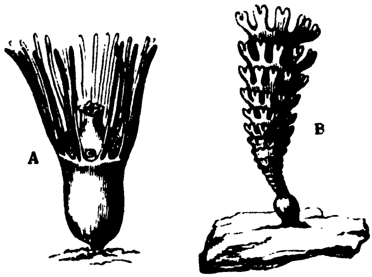
Thus on a closer examination we find that the despised sea-blubbers, from which even a naturalist like Réaumur turned with contempt as from mere lumps of animated jelly, possess in reality a highly interesting organisation, and our admiration increases when we find that creatures endowed with con-

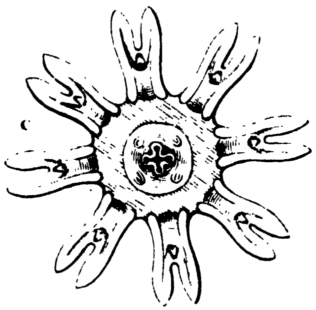
siderable powers of perception, and some strength and agility, are formed but of a few delicate tissues filled with a fluid to all appearance not very different from sea water, and shrinking to a mere nothing when deprived of their vital power. Thus of a Medusa or Rhizostoma weighing from twenty to thirty pounds but few traces remain after death, the ground is covered with a light varnish, all the rest has been absorbed by the thirsty sands.

The motion of the Discophora is performed by alternate contractions and expansions of the umbrella, repeated at regular intervals, something like the movement of the lungs in respiration, each contraction forcibly expelling a jet of water, which, impinging on the surrounding fluid, causes a reaction, through which the animal is forced forward with a jerk in the opposite direction. By contracting the whole or only part of its disk, the Medusa has it in its power to direct its movements, and while thus swimming along with the convex end of the umbrella directed forwards, and its fimbriated vessels and tentacula streaming behind, it may well rank among the most elegant children of the sea. Nor are its long thread-like tentacles mere accessorial ornaments or innocent organs of touch, for they are generally armed with the same 'urticating organs' which render the Actinias and many other polyps formidable to the smaller sea-animals, and after having thus paralysed resistance, are admirably adapted for curling round their prey, and conveying it by their retraction to the mouth.

But the most remarkable passage in the history of the Discophora is the wonderful alternation of their generations. The Medusa first gives birth to a multitude of minute gelatinous bodies, in shape not unlike the eggs of a sponge, or the spores of one of the lower algæ, and like them furnished with a multitude of cilia, which by their motion propel the little body through the water. When emitted, the bud is of an oval shape, broader at one end; and it constantly keeps its broader end in advance when moving. Internally it presents a cavity, so that it is in fact a little bag of living jelly clothed with vibratile hairs. After a while the bud attaches itself by its larger extremity or apparent front to any convenient object, such as a stone or the stalk of a sea-weed, and this extremity henceforth becomes the base on which all its future operations are con-

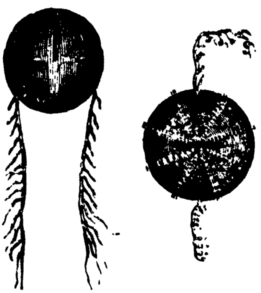
ducted. The body lengthens and becomes wider upwards, tentacles form round the mouth (A) and then new buds sprout forth successively (B), which, finally detaching themselves from the parent stock (C), swim about as perfect Medusæ, whose eggs in their turn are destined to perform a similar cycle of changes. Many marine animals, which, before this wonderful alternation of generations became known, were reckoned among the polyps, have now been found out to be mere sessile forms of Acalephæ, and future investigations will no doubt considerably add to their number, and point out the nearest relationship or rather the identity of many species, still supposed to belong to distinct orders of animated beings.





Medusa Larvæ.

The ribbed or Ciliograde Jelly-fishes are distinguished from the Discophora by their external generally globular or egg-shaped form, and by their internal structure and peculiar mode of progression. While the Discophora move along by propelling a jet of water against the surrounding liquid, locomotion is here produced by innumerable flat plates or little paddles, attached to longitudinal equidistant bands or ribs which divide the crystalline body into equally large segments or fields. When the animal wishes to swim backwards or forwards, it sets all its paddles in motion, and glides rapidly and gracefully through the water by their united power. When it wishes to turn, it merely stops the movement of its paddles on one side. When these

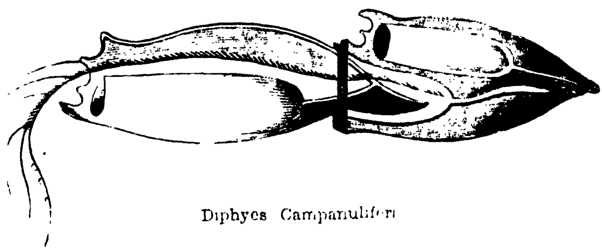


Cydippe.

delicate little oars are in activity, their crystalline surfaces reflect the sunlight in brilliant prismatic colours, or flash in the darkness with a beautiful blue light.

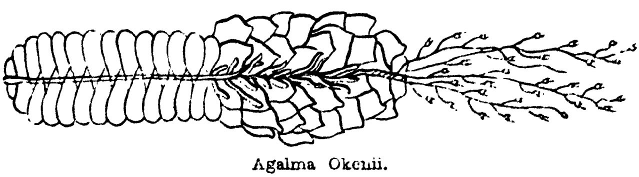
The fishing apparatus of many of the ciliograde acalephæ is no less elegant than their locomotive organs. It consists of two exceedingly slender tentacles emerging from the under part of the body, which, though five or six inches long when fully extended, are capable of being wholly withdrawn within the body of the creature, where they are lodged in tubular sheaths. On one side they are provided at regular intervals with shorter and much thinner filaments, which roll together spirally when the chief tentacle contracts, and expand when it is stretched forth. Each of them might be compared to an angle-rod, as it is armed with those urticating darts that prove so formidable to many of the lower marine animals. In those species which are unprovided with tentacles, such as the beroe, a widely-gaping mouth supplies their place.

The tubular acalephæ differ very much from each other in form, and are generally so strangely constructed that descrip-



Diphyes Campanulifera

tion is as inadequate to give a clear idea of them, as painting is to do justice to their crystalline transparency and beauty of colour. Thus the diphyæ consist of two tubular pieces fitting one within the other, and the stephanomiæ or agalmas of a

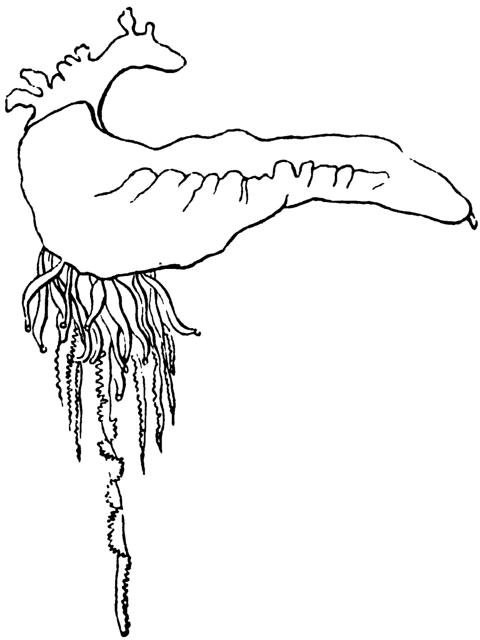


Agalma Okenii.

long chain of cut diamonds, some vesicular, and others with numerous appendages and tentacles. At the least shock the

members separate and float about on the surface, when in course of time they most likely, like the polype, reproduce a new commonwealth.

In the Physalus, or Portuguese man-of-war, the organ of locomotion is a large air-filled vesicle or bladder, which for the most part rises above the surface of the water, displaying every shade of purple and azure. Numberless short sucking-tubes and long tentacles hang in beautifully blue and violet

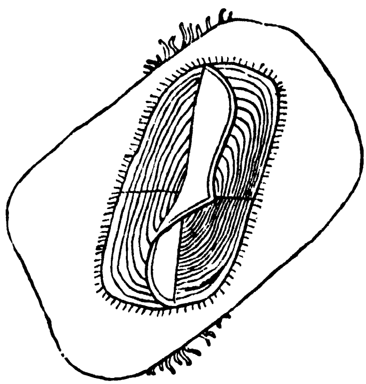


Physalus utriculus

coloured locks or streamers from the lower surface of the body. The tentacles can at pleasure be rolled together or extended to the length of many feet, and woe to the unlucky fish or cephalopod that comes within their reach, for, embracing the doomed creature with the rapidity of lightning, they paralyse all resistance by means of the venomous secretion of their urticating organs.

In the Velella, locomotion is effected partly by the movements of the numerous tentacles which hang down from the inferior surface, but chiefly, perhaps, by the action of the

wind on the thin transparent crest, which rises vertically along the back and catches the moving breeze. The disk from which the tentacles hang, and the crest, are supported internally by a calcareous plate containing numerous cells filled with air, which renders the whole animal so buoyant that it floats on the surface of the water and is wafted along by the winds.



Velella Septentrionalis.

The importance of the acalephæ in the economy of the ocean corresponds with their vast numbers and their wide geographical range; for though many are confined to the waters of the torrid zone, yet even the seas of Spitzbergen have been found scintillating with vast shoals of the cydippe. They supply in a great measure the food of the whale, and, converted into blubber, attract the bold mariner to the Arctic seas; innumerable molluscs and crustaceans prey upon their inexhaustible legions, and are in their turn devoured by the herrings, whose capture is a source of abundance to whole nations of fishermen. Who can count the millions which every moment destroys, and who can think without admiration of those prodigal sources of life which constantly fill up the void, and maintain their hosts from age to age?

CHAPTER XVIII.

ECHINODERMATA.

Primeval Sea-stars.—Feather-stars.—Snake-stars.—Star-fishes.—Their Suckers and Mode of Locomotion.—Their Skeleton.—Their Victims and their Enemies.—Sea-Urchins.—Structure of their Shell.—Their Dental Apparatus.—Pedicellariæ, or Sea-Cucumbers.—Metamorphoses of the Echinodermata.

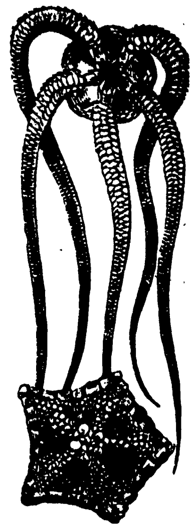
At that far-distant period of the earth's history when the swampy lowlands were covered with those thickets of calamites and stigmarias whose remains have given birth to the coal strata of the present day, the bottom of the ocean was paved in many places with crinoid star-fishes, whose bodies, branching out into delicately feathered bifurcated arms, were affixed like flowers to a slender articulated stalk.

Their petrified skeletons, imbedded in countless numbers in many of the calcareous strata of our island, bear witness to their ancient importance; but the beautiful and antique race of these Lily Encrinites and Pentacrinites is now reduced to but one single representative in the British seas—the rosy feather-star, whose *long and delicately fringed ray, and deep rose colour dotted with brown, may serve to give us an idea of the beauty of the submarine landscapes at the time when the bottom of the* sea was peopled with gigantic specimens of the same class. Attached in its infancy to a stalk like its mightier predecessors, it swims freely about at a later period, by alternately contracting and extending its closely-feathered arms. It is found all round our coasts, and is frequently brought up in from ten to twenty fathoms water, attached to different kinds of seaweed, which it lays hold of by means of the claws which tip the filaments that clothe its body.

Thus the crinoid star-fishes have mostly disappeared, but the asteroidea, forming the two great subdivisions of the snake-

stars and star-fishes, that have usurped their place, abound in the modern ocean, and frequently, like their predecessors of old, cover the bottom of the sea with a living carpet.

The snake-stars are essentially distinguished from the true star-fishes by the long serpent or worm-like arms which are appended to their round, depressed, urchin-like bodies. They have no true suckers with which to walk, their progression being effected (and with great facility) by the twisting or wriggling of their arms, which are, moreover, in many species furnished with spines on the sides, assisting locomotion over a flat surface. These arms are very different from those of the true star-fishes, as they are not lobes of the body as in the latter, but mere processes attached or superadded to the body. In the sand-stars and brittle-stars they are simple; but in the Scotch Argus or Warted Euryale, of which the adjoining woodcut represents a segment, each of the five rays is branched again and again, so that the whole resembles a bunch of serpents' tails. While swimming, this strange creature spreads and stretches out all its branches to their full length, but when a desirable prey comes within their reach, it suddenly contracts their Gorgon coils and entraps its victim as in the meshes of a net. As the *expanded Argus measures about a foot in diameter, it may well be supposed* that it is no contemptible enemy for with on its way.

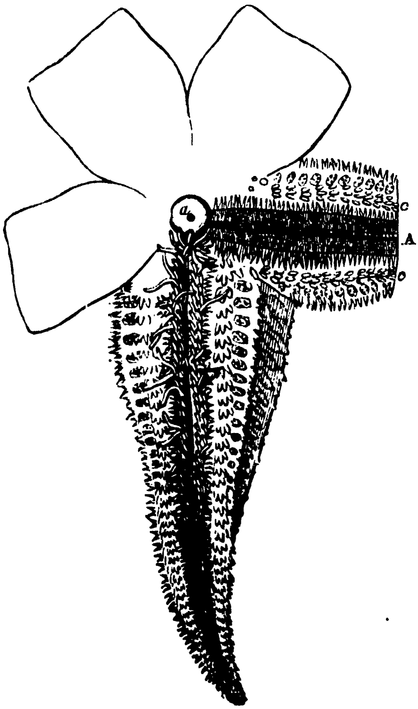


Sand-star.

Warted Euryale.

The brittleness of the snake-stars is highly remarkable, for at the slightest touch they separate themselves into pieces with wonderful quickness and ease. Touch the common brittle-star, and it flings away an arm; hold it, and in a moment not a process remains attached to the body. 'The common brittle

star,' says Edward Forbes, 'often congregates in great numbers on the edges of scallop banks, and I have seen a large dredge come up completely filled with them; a most curious sight, for when the dredge was emptied, these little creatures, writhing with the strangest contortions, crept about in all directions, often flinging their arms in broken pieces around them; and their snake-like and threatening attitudes were by no means relished by the boatmen, who anxiously asked permission to shovel them overboard, superstitiously remarking that "the things wern't altogether right."' There can be no doubt that, thanks to this facility of dismemberment, the brittle-stars disappoint many a hungry foe of at least part of his meal, and wriggle out of his reach while he feasts on one of their cast-off arms.

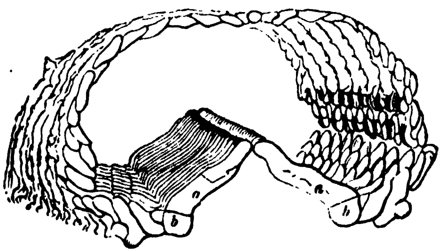


Inferior view of Asterias Rubens.
At A part of the feet is removed. a mouth. c spines.

The locomotive apparatus of the true star-fishes is of a much more complicated structure than that of the snake-star; for as they are born not to swim, but slowly to creep along upon the bottom of the sea, the grooved under-surface of their arms is provided with two or four rows of small worm-like suckers, which, alternately extending and contracting, serve to drag the body after them. The strength and activity of these little organs afford an entertaining spectacle when a star-fish is placed on its back in a plate filled with sea-water. At first the creature remains motionless; for, offended by the rough treatment it has undergone, the feet have all shrunk into the body, leaving nothing visible but a series of minute tubercles, but soon they are seen to emerge like so many little worms

from their hole, and to grope backwards and forwards through the water, evidently seeking the nearest ground to lay hold of. Those that reach it first, immediately affix their suckers, and, by contracting, draw a portion of their body after them, so as to enable others to attach themselves, until, pulley being added to pulley, their united power is sufficient to restore the star-fish to its natural position.

This act of volition is surely remarkable enough in an animal which hardly possesses the rudiments of a nervous system, but the simple mechanism by which the suckers are put into motion is still more wonderful. Each of these little organs is tubular, and connected with a globular vesicle filled with an aqueous fluid, and contained within the body of the star-fish, immediately beneath the hole from which the sucker issues. When the animal wishes to protrude its feet, each vesicle forcibly contracts, and propelling the fluid into the corresponding sucker, causes its extension; and when it desires to withdraw them, a contraction of the suckers draws back the fluid into the expanding vesicles. All these little bladder-like cavities are connected



Section of a ray of Asterias Rubens,

Showing the arrangement of the calcareous pieces. *a* oblong calcareous plates united in the median line. *b* smaller lateral plates.

with vessels, which communicate with a vascular circle surrounding the mouth; while the internal walls, both of the suckers and the system of communicating vessels, are furnished with vibratory cilia, through whose agency a continual circulation of the fluid they contain goes on within them, and serves to aërate the blood.

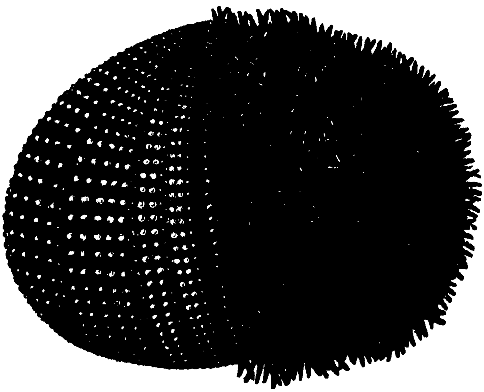
Not only the suckers, but also the rays from which they proceed, are extremely flexible in every direction, for the skeleton of a star-fish, or that part which remains when all the soft flesh has been removed, is a wonderfully beautiful structure, consist-

ing of hundreds of nicely-fitted calcareous pieces arranged in a regular pattern, perfectly symmetrical in all its parts; so that the supple animal finds no difficulty in making its way through the crevices of a rocky shore, or in traversing the intricate tangles in search of prey. The march of the sea-star is indeed but slow, and hosts of little marine animals on which he would willingly feed, no doubt escape his voracity, as they have been gifted with a greater agility; yet his table is richly furnished, for there are hosts of molluscs that are not only more tardy than himself, but even firmly rooted to the ground, and have nothing to oppose to his attacks but the passive resistance of their closed valves.

This defence, however, is frequently of no avail, for star-fishes are not unfrequently found feeding on shell-fish, enfolding their prey within their arms, and seeming to suck it out of its shell with their mouths, pouting out the lobes of the stomach, which they are able to project in the manner of a proboscis. Possibly the stomach secretes an acrid and poisonous fluid, which, by paralysing the shell-fish, opens the way to its soft and fleshy parts. Thus the star-fish is a sworn enemy to oyster banks, and consequently also an indirect enemy to man; but fortunately he himself is an object of pursuit to greedy crabs, cephalopods, and fishes, who, however, are frequently at some pains to catch him; for it is no easy matter to detach him from the rock to which he clings, and the spines which frequently cover his coriaceous back are likewise no despicable means of passive defence.

The sea-star might be called a flattened sea-urchin with radiated lobe, and the sea-urchin a contracted or condensed sea-star, so near is their relationship. Still there are notable differences between them. Thus, in the sea-urchins, the digestive organs form a tube with two openings, while in the sea-stars they have but one single orifice. The mouth of the latter, which may be so dilated as to admit large mollusca in their entire shell, has only toothed processes projecting into its cavity, but that of the sea-urchin is a masterpiece of mechanical contrivance. Fancy five triangular bones or jaws, each provided with a long projecting moveable tooth. A complicated muscular system sets the whole machinery going, and enables the jaws to play up and down, and across; so that a more effective mill for grinding down the food cannot well be conceived.

The calcareous shell of the sea-urchin seems at first sight to be composed of one simple crust, but proves on nearer inspection to be a beautiful piece of mosaic, consisting of several hundred parts, mostly five-sided, transversely oblong, and disposed in twenty vertical rays or columns. Ten of these are narrower, and consist of smaller pieces, which are perforated with holes for the feet or suckers; they are thence termed ambulacral: the other ten are broader, and consist of larger pieces. The ten ambulacral columns are disposed in five pairs, with which the ten larger columns, also disposed in pairs, alternate. The number of plates in a row varies with the age of the animal, increasing as it grows older and larger. They are marked

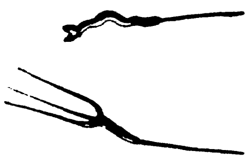


Shell of Echinus, or Sea-Urchin.

on the outside with tubercles or knobs of various sizes, which support the spines. The spines themselves have a cup-like cavity at their base, which is connected with, and moves on, the prominent tubercle. The pieces of which the shell is composed are so closely united that their junctions are hardly visible, but on allowing the shell to macerate for some days in fresh water, it falls to pieces. This complicated structure is by no means a mere architectural luxury, a useless exuberance of ornament, but essentially necessary to the requirements of the animal's growth. A simple hard crust would not have been capable of distension, whereas a complicated shell, such as the sea-urchin possesses, can grow in the same ratio as the internal parts, by continual deposits on the edges of the individual pieces. On closely examining a living sea-urchin, we find the whole surface

of the shell and spines covered with a delicate skin, which, in spite of their close connexion, penetrates into the intervals of the several pieces. This membrane secretes the chalk of which the shell is composed, and deposits fresh layers on the edges of the plates, so that in this manner the shell continually widens until the animal has attained its perfect size. The spines are secreted in the same manner by the soft integument which effects their union with the shell at the circumference of their articulation, and exhibit under the microscope an admirable beauty and regularity of structure. So bountifully has the Great Architect of worlds provided for the poor insignificant sea-urchin!

Besides the spines there exist on his external surface multitudes of exceedingly minute and beautifully formed pincers, which as long as the animal lives are in perpetual motion, bending about from side to side, and opening and shutting their three-forked apex continually. These most singular organs, which are also found on many of the star-fishes, (where, however, they are simply forked like the claws of a crab in miniature,) are called by naturalists pedicellariæ, and were formerly regarded as parasitic creatures; but from the accurate observations of Mr. Gosse, there can be no doubt that, though their uses are still wholly unknown, they are truly and essentially organic parts of the animal. Both the suckers and the spines serve the sea-urchin as organs of locomotion. With the former he firmly moors himself to the ground, and with the latter some species are able even to entomb themselves, pholas-like, in stone. Thus the Echinus lividus inhabits circular cavities evidently formed by himself, and so deep as to embrace two-thirds of his bulk. The burrow is large enough to admit of the creature rising a little, but not of its coming out easily. The echinus adheres so firmly to this cavity by his suckers, as to be forced from it with extreme difficulty when alive. On the coasts of the county of Clare thousands may be seen lodged in the rock, their purple spines and regular forms presenting a most beautiful appearance on the bottoms of the grey limestone rock pools. How the boring is performed has, like many other secrets of creation, not yet been



Pedicellariæ.

settled by naturalists. The first perforation is most likely effected by means of the teeth, and then the rock softened by some secreted solvent.

On our coasts the common egg-urchin affords *the poor a some*what scanty repast, and throughout the Mediterranean *its greater* size, and also that of its allies (Echinus melo, sardicus), render them, when 'in egg,' conspicuous objects in the fish markets; but as articles of food and trade they are far surpassed by the holothuriæ, or sea-cucumbers, which are caught by millions, and give employment to thousands of fishermen on the Indian Ocean, or among the isle-clusters of the Pacific. These animals may be regarded, in one light, as soft sea-urchins; and, in another, as approximating to the annelides or worms. Their suckers are similar to those of the true star-fishes and sea-urchins. Besides progression by means of these organs, they move like annelides, by the extension and contraction of their bodies. The mouth is surrounded by plumose tentacula, the number of which is always a multiple of five. They all have the power of changing their shapes in the strangest manner, sometimes elongating themselves like worms, sometimes contracting the middle of their bodies so as to give themselves the shape of an hour-glass; and then again puffing themselves up with water so as to be perfectly globular. Under the influence of terror they dismember themselves in the strangest manner. Having no legs or arms to throw off, like their relations the brittle-stars, they simply disgorge their viscera and manage to live without a stomach, no doubt a much greater feat than if they contrived to live without a head. The loss is, however, made up in course of time by a wonderful power of regeneration, even if the process of disgorgement was so complete as to leave but an empty sack behind.

Nothing can be more curious than the developmental history of the echinoderms, for here the embryonic mass is converted, not into a larva, which subsequently attains the adult form by a series of metamorphoses, but into a peculiar *zooid*, which seems to exist for no other purpose than to give origin to the echinoderm by a kind of internal germination, and to carry it to a distance by its active locomotive powers so as to prevent the spots inhabited by the respective species from being overcrowded by the accumulation of their progeny.

The larval zooids are formed upon a type quite different from that which characterises the adults, for instead of a *radial* symmetry they exhibit a *bilateral*, the two sides being precisely alike, and each having a ciliated fringe along the greater part or the whole of its length. Such are the changes they undergo in the progress of their growth, that in the fully developed star-fish and sea-urchin the only part retained is a portion of the stomach and intestine, which is pinched off, so to speak, from that of the larval zooid by the animal's forcible contractions.

Many of the details of this wonderful history are still unknown, and undoubtedly belong to the most interesting secrets of the life of the seas.

CHAPTER XIX.

MOLLUSCA.

The Flustra or Sea-mats.—Avicularia.—Metamorphoses of the Flustra.—Salpæ and Ascidiæ.—Botrylli.—Pyrosomata.—Bivalve Shell-fish.—Free and Sessile.—The Byssus.—The File of the Pholades.—Respiration of the Bivalve Shell-Fish.—Their Nourishment.—Snails.—Their Masticatory Apparatus.—Their Cautious Habits.—Pteropods.—Conical Appendages of the Clio's Head.—Its wonderful Dental Apparatus.—Cuttle-Fish.—Sucking-Disks.—The Onychoteuthis.—Number and Importance of the Molluscs.

THE naked slug lazily crawling in damp weather over our garden and forest-paths, the oyster firmly attached to the bottom of the sea, the many-armed cuttle-fish rapidly darting through the waters, and the ponderous whelk slowly dragging along its heavy shell in the deeper waters beyond the recess of the tide, are no doubt very dissimilar in their outward form and in their mode of life; but on examining their internal structure a close relationship becomes apparent, and thus they are all comprised by naturalists under the vast class of the molluscs which spreads in countless legions over the surface of the globe, but chiefly inhabits the seas; as of the living species, whose number is estimated at 16,732, more than 10,000 are denizens of the ocean.

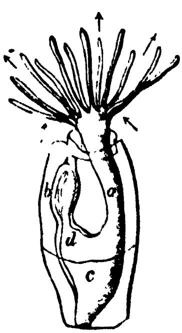
The molluscs are distinguished from all other animals by the following characters:—Their bodies are soft, but almost all of them have a peculiar development of the skin which covers their body like a mantle, and generally secretes a hard, inarticulated, and consequently inflexible, calcareous or horny shell. Their blood is white, flows from the heart to all parts of the body, and finds its way back again to that organ after having been refreshed either in lungs, or, more frequently, in a branchial apparatus. Their muscles are attached to various points of their skin, forming more or less dense and complex

tissues. The vegetative organs are very much developed, and generally disposed in a curve, so that the mouth is proximate to the opposite extremity of the intestinal canal. From the crustaceans and insects they are distinguished by the absence of jointed feet, from the fishes by the absence of an internal skeleton and spinal marrow. A view of the various subdivisions of this great class, proceeding from the lowest to the highest types of mollusc organisation, will show us that, though generally weak and inert, they are all most admirably fitted out for the battle of life.

While wandering on the beach we not seldom find, among the relics of the retiring flood, pale-coloured leaf-like formations, of a papery substance, which might be mistaken for dried sea-weeds, blanched by exposure to the air. But a narrower inspection soon shows that the flustræ, or sea-mats, as these marine productions are called, are of a much more complicated structure than that of a simple alga, as they are built up of innumerable little oblong cells, placed back to back, like those of a honeycomb; and each crowned (as may readily be seen with the help of a pocket lens) by four stout spines.

Leaf-like Sea Mat.

Before the stormy tide detached these foliaceous formations from the bottom of the sea, and left them to perish on the shore, each of these cells contained a living creature, whose mouth was surrounded with a coronet of filiform and ciliated tentacles, destined to produce a vortex in the water, and thus to provide their tiny owner with its food. The body was bent on itself, somewhat like the letter V; the one branch (a) being the mouth and throat, the other (b) the rectum opening by an anus, and the middle part (c) the stomach, probably with some accessory organ. The tenant of each cell, though enjoying an independent existence, was linked at the same time by a common circulation to the proprietors of the cells above and below him, and thus the whole formed a community of perhaps forty or fifty thousand



Flustra in its cell. Highly magnified.

individuals, similar to the social republics of the polyps. But in spite of this apparent resemblance, the flustræ have a far more developed organisation; for besides the rudiments of a nervous system, which directs the independent movements of each individual, and establishes by connecting filaments the unity of the colony, they possess a very complicated muscular apparatus, a complete digestive canal, and when they draw back their tentacles, they are able to close their little cells by a kind of moveable lid, which no doubt affords them security against a host of microscopical foes. When fresh, the whole structure exhales an agreeable acid odour, somewhat like that of the lemon-scented verbena or geranium, but less pure.

Besides the flustræ, the sea contains a great variety of allied genera, some erected like them on short stalks (cellulariæ), while others spread in concentric layers over sea-weeds or shells (lepraliæ), and though appearing to the naked eye as rude and unsightly scurfs, exhibit, when magnified, a wonderful diversity and elegance of form. Other genera are tubular (tubuliporæ), others spongy (celleporæ). Generally the cellular extension is unbroken, but sometimes (reteporæ) the leaf-like expansion is pierced like net-work. Such is the exuberance of fancy displayed in the formation of the group of the polyzoa, as this humblest subdivision of the great series of molluscous animals has been named.

But a closer inspection reveals still greater wonders to the marine microscopist, for most of the polyzoa, and particularly the cellulariæ, possess very remarkable appendages or processes, presenting the most striking resemblance to the head of a bird. Each of these processes or 'aviculariæ' has two 'mandibles,' of which one is fixed like the upper jaw of a bird, the other moveable like its lower jaw; the latter is opened and closed by two sets of muscles, which are seen in the interior of the head, and between them is a peculiar body, furnished with a pencil of bristles which is probably a tactile organ, being brought forwards when the mouth is open, so that the bristles project beyond it, and being drawn back when the mandible closes. During the life of the polyzoon, these tiny 'vulture-heads,' which are either sessile or pedunculated, keep up a continual movement; and it is most amusing to see them see-sawing, and snapping and opening their jaws, and then sometimes in their incessant

activity even closing upon the beaks of their neighbours. No one has yet divined the economy of these most singular organs, but as several observers have noticed the seizure of small roving animals by their pincer-like beaks, the conclusion is pretty general that they are in some way connected with the procuring of food.

But it seems to have been forgotten, not only that the 'aviculariæ' have no power of passing the prey thus seized to the

A Portion of a Cellularia magnified. B A bird's-head process, more highly magnified and seen in the act of grasping another.

mouth, but also that the mouth is situated at the bottom of a funnel of ciliated tentacles, and is calculated to receive only such minute prey as is drawn within the ciliary vortex. Thus they cannot possibly serve as immediate or direct purveyors of food; but Mr. Gosse explains to us, in a very satisfactory manner, how the seizure of a passing animal, and the holding of it in their tenacious grasp until it dies, may be the means of attracting the proper prey to the vicinity of the mouth.

'The presence of decomposing animal substance in water,' says this distinguished naturalist, 'invariably attracts crowds of infusory animalcules, which then breed with amazing rapidity so as to form a cloud of living atoms around the decaying body, quite visible in the aggregate to the unassisted eye; and these

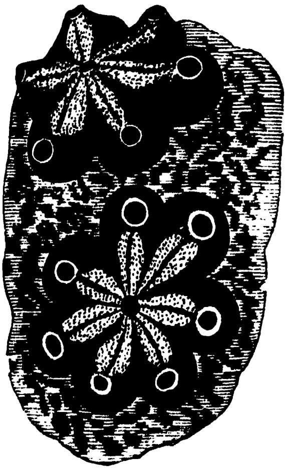
remain in the vicinity, playing round and round, until the organic matter is quite consumed. Now, a tiny annelide or other animal, caught by the "bird's-head" of the polyzoa, and tightly held, would presently die; and though, in its own substance, it would not yield any nutriment to the capturer, yet by becoming the centre of a crowd of busy infusoria, multitudes of which would constantly be drawn into the tentacular vortex and swallowed, it would be ancillary to its support, and the organ in question would thus play no unimportant part in the economy of the animal.'

Besides the 'avicularia,' most of the polyzoa are furnished with 'vibracula,' long bristle-shaped organs, each one springing at its base out of a sort of cup that contains muscles by which it is kept in almost constant motion, sweeping slowly and carefully over the surface of the polyzoary, and removing what might be injurious to the delicate inhabitants of the cells when their tentacles are protruded. So carefully have all the wants of these humble creatures been provided for!

The nearest relations of the polyzoa are the tunicated mollusca, so called because their soft parts are enclosed, not in a shell, like the majority of the class, but in a tough leathery coat or tunic. To this subdivision belong the various kinds of Ascidiæ, both simple and compound, the Salpæ and the Pyrosomas. The simple Ascidiæ, or sea-squirts, are sometimes found attached to sea-weeds and stones in the littoral zone, while others are frequently thrown up from deeper water on the beach. Some are of a large size, several inches in length. Their outer form is that of a bag with a smooth or variously roughened semi-transparent skin, furnished with two small openings, from which, on the slightest pressure, a jet of water is sent to a considerable distance. These creatures lead a very inactive life. Adhering by their base to rocks, shells, and other submarine

Ascidia Mammillata.
a branchial orifice, open. *b* anal orifice, closed.

substances, they trust for nourishment to whatever small fry are brought to their mouths by currents in the water. They have not the elegance of form of the sea anemones, but many are painted with the most gaudy colours.



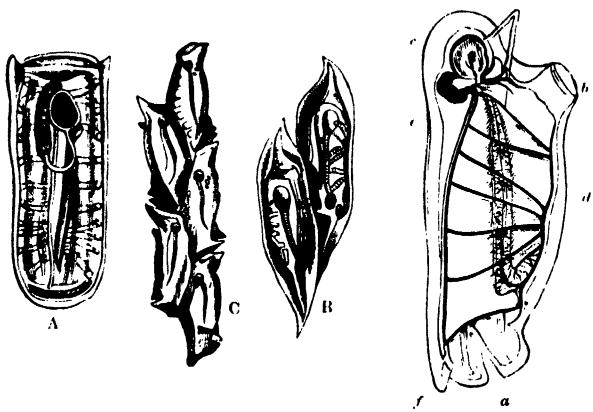
Botryllus violaceus, highly magnified. *a* common test. *bb* some of the bronchial orifices. *c* the common anal orifice of one of the systems.

'If, when walking on the sea-shore, about low-water mark,' says Forbes in his History of British Mollusca, 'we turn over large stones, or look under projecting eaves of rock, we are almost sure to see translucent jelly-like masses of various hues of orange, purple, yellow, blue, grey, and green, sometimes nearly uniform in tint, sometimes beautifully variegated, and very frequently pencilled as if with stars of gorgeous device; now encrusting the surface of the rock, now descending from it in icicle-like projections. These are compound Ascidians. A tangle of broad-leaved fucus, torn from its rocky bed or gathered on the sand, where the waves have cast it after storms, will show us similar bodies, mostly those star-figured (botrylli), investing its stalks, winding among the intricacies of its roots, or clothing with a glairy coat the expanse of its foliated extremities. In examining these bodies, we find that it is not a single animal which lies before us, but a commonwealth of beings, bound together by common and vital ties. Each star is a family, each group of stars a community. Individuals are linked together in systems, systems combined into masses. Indeed, few bodies among the forms of animal life exhibit such exquisite and kaleidoscopic figures as those which we see displayed in the combinations of the compound Ascidians.

Both in the solitary and compound Ascidians, the young animal, when it first issues from the egg, has active powers of locomotion, being provided with a large tadpole-like tail, by the aid of which it is propelled through the water. Then the tail disappears, and grasping fibres or roots spring from the body, which gradually assumes the form and adopts the quiet

life of the parent from which it sprung. It is thus, by giving to the young animal a locomotive power which she denies to the fully grown, that nature, in these and many other of the stationary marine animals, provides for the proper dispersion of the species. Among more perfect animals, the old take care of the young, and provide for them; here we find the young possess instincts and organs which they lose at an advanced period of their life, when they would be no longer necessary, thus beautifully balancing the wants and the means of satisfying them.

While the sessile Ascidiæ remind one of the polyps, the transparent Salpæ, freely swimming in the ocean, bear a great resemblance to the pellucid jelly-fishes, or Medusæ. Each



A. Salpa runcinata solitary. B. S. runcinata associated, C. S. zonaria aggrega D. S. maxima.

a posterior orifice. *b* anterior orifice. *c* abdomen. *d* branchial lamina. *e* heart. *ff* prolongations of the test, by which the animal is adherent to its neighbour.

resembles a crystalline tube, through which one can distinctly see the internal coloured parts. Sometimes these animals are found solitary, at other times associated in circular or length ened groups, termed garlands, ribands, and chains. The salpa-chains, varying in length from a few inches to many feet, swim through the tranquil water with a regular serpentine movement, and are often regarded by sailors as sea-serpents; but when taken from the water, the individuals of the group are easily detached. Thus, in consequence of accidents, separate members of these chains are often met with in seas abounding with these molluscs; but other separate salpæ are also met with that have never been united to others, and differ considerably

in form from the associated ones. Yet, strange to say, these solitary salpæ are the young of salpæ that have been chained, and the progeny of these solitary ones will be chained salpæ; consequently, as Chamisso, the first discoverer of this remarkable alternation of generations, graphically observes, 'a salpa mother is never like its daughter or its own mother, but resembles its sister, its grand-daughter, and its grandmother.'

The tubular body of the salpæ is open at both ends, the posterior aperture being provided with a more or less perfect valvular apparatus, which can be opened or closed at pleasure. They move slowly along by alternate expansions and contractions, by admitting the water through the posterior aperture, and expelling it through the opposite orifice.

The Pyrosomes consist, like the compound Ascidians, of large colonies of small individuals aggregated in the form of a cylinder open at one end. Their mouths or anterior extremities are situated on the exterior of this hollow body, which they bristle with large and longish tubercles, whilst the opposite or anal orifices open into the cavity of the cylinder, whose smooth wall they perforate with numerous small holes. By a simultaneous action the central cavity is either narrowed or enlarged, and by this means the strange social republic glides slowly through the waters. They inhabit the Mediterranean, and the warmer parts of the ocean. In the former, at times, their abundance is a source of dread to the fishermen, sometimes even completely clogging their nets; and in certain oceanic regions they are met with in almost incredible profusion. Their delicate and transparent forms, their elegant tints, and their unrivalled phosphorescence render them the most beautiful of molluscs, and objects of admiration to the naturalist and the voyager.

Mr. Bennett relates that, during a voyage to India, the ship, proceeding at a rapid rate, continued during an entire night to pass through distinct but extensive fields of these molluscs, floating, and glowing as they floated, on all sides of her course. Enveloped in a flame of bright phosphorescent light, and gleaming with a greenish lustre, the pyrosomes, seen at night in vast shoals upwards of a mile in breadth, and stretching out until lost in the distance, present a spectacle the glory of which may be easily imagined.

'In the evening of the 13th Frimaire,' says M. Peron, who

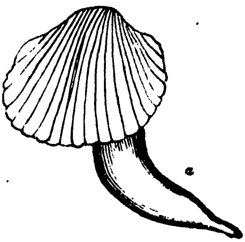
first discovered and established the genus, 'we experienced one of the strongest of the short-lived storms peculiar to the region of calms in the Atlantic. The sky was on all sides loaded with heavy clouds; all around the obscurity was profound; the wind blew violently, and the ship cut her way with rapidity. Suddenly we discovered at some distance a great phosphorescent band stretched across the waves, and occupying an immense tract in advance of the ship. Heightened by the surrounding circumstances, the effect of this spectacle was romantic, imposing, sublime; rivetting the attention of all on board. Soon we reached the illuminated tract, and perceived that the prodigious brightness was certainly and only attributable to the presence of an innumerable multitude of largish animals floating with the waves. From their swimming at different depths, they took apparently different forms; those at the greatest depth were very indefinite, presenting much the appearance of great masses of fire, or rather of enormous reddish cannon-balls; whilst those more distinctly seen near the surface perfectly resembled incandescent cylinders of iron.'

The Conchifera, or the molluscs contained within a bivalve shell, comprise the two groups or orders of the Brachiopoda and the lamellibranchiate bivalves. The former, which are chiefly fossil, occur only in a few genera in the present seas, and are characterised by the two long fleshy ciliated and spiral arms which they use for opening their shell. Their mantle is organised so as to be serviceable for respiration, and the numerous cilia with which their arms are covered produce the currents that both provide them with food and aërate their blood. They generally live in the deeper seas, either attached to other bodies by a sinewy stalk proceeding from an orifice at their apex, or fixed, like the oyster, by their shells.

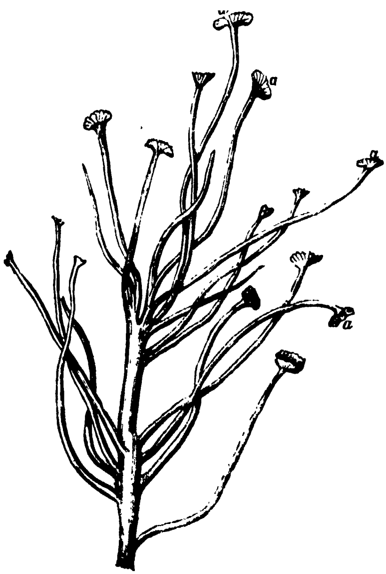
The lamellibranchiate bivalves, which are spread in several thousand species over all the seas from the poles to the equator, play a far more important part than the brachiopods in the present economy of nature. Every flood casts their empty shells upon all the coasts of the ocean, and their shattered valves are almost as numerous as the sands which line its shores. Their forms and their colours are as various as their modes of life, but their structure is in every case exactly suited to their wants.

Those which, enjoying a free life, are capable of wandering from place to place, or at least of changing their position,

possess a more or less developed and variously-shaped muscular foot, which they protrude at will from between the folds of their mantle. By means of this organ many are able to dig a hole or furrow in the sand, which enables them to baffle the pursuit of many enemies, others to advance with a crawling movement or even to make jumps along the sand. Thus the common cockle stretches its foot (*a*) out as far as possible, presses it against the ground, springs up by suddenly contracting it, and, by repeating the process again and again, hops along at a pace one would hardly expect to meet with in a mollusc. In other genera, where the foot exists but in a small or rudimentary form, the sudden opening and shutting of the valves supplies its place as a means of locomotion. In this manner the scallop, which inhabits deep places where it lies on a rocky or shelly bottom, swims or flies through the water with great rapidity, and the file or rasp-mussel, a closely-related genus, principally occurring in the Indian Ocean, glides so swiftly along that even a light-footed pursuer is hardly able to catch it. In several of the sedentary genera, the foot, useless as an organ of locomotion, is reduced to the functions of spinning a long lustrous and silky fasciculus or bundle of filaments called *byssus* or beard, which serves to affix the animal to any solid body sunk in the sea. Generally the connection is permanent, but some species, among others the edible mussel, are able to detach the filament from the glandular pedicle situated at the inferior base



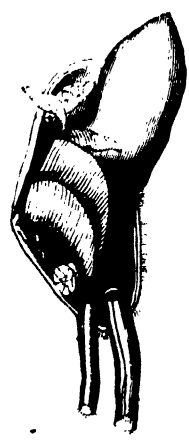
Common Cockle.



Filament of a Byssus, highly magnified.
a a a a disc-like expansions.

of the foot which originally secreted them, and then to attach themselves anew to some other object. If the byssus be examined under a powerful lens, before any of the filaments are torn, it is easy to perceive that these are fixed to submarine bodies by means of a small disc-like expansion of their extremities of various extent according to the genus and species.

The pholades, which have very delicate milky-white valves, burrow holes in limestone or sandstone rocks, though occasionally they content themselves with houses of clay. How shells as thin as paper and as brittle as glass are able to work their way through hard stone has long been a puzzle to naturalists, some of whom asserted that they attained their object by means of an acid solvent, others that they bored like an auger by revolving, but recent investigations have discovered that their short and truncated foot is the chief instrument they use in their mining operations. For it is not only extremely muscular, but provided at its base with a rough layer of sharp crystals of flint, which when worn off are soon replaced by others, and act as excellent files. Thus we find in the same class of animals the same organ most variously modified in form and structure, now serving as a foot, now as a spade, or as a spinning-machine or a rasp, and throughout all these modifications admirably adapted in every case to the mode of life of its possessor. The burrowing molluscs must have been in perpetual danger of suffocation if their branchiæ had not been carefully protected against the ingress of mud or sand. To prevent this danger, their respiration is generally effected by means of a double siphon (*a b*), one for the entrance and the other for the exit of the water, a perpetual change of which is absolutely indispensable to the life of the animal. The interior of these tubes is lined with innumerable delicate cilia, by the action of which the surrounding water is drawn towards the entering orifice, and conveyed in a strong current through the tube over the surface of the gills. Then, having been deprived of its oxygen, it is poured through the other tube, and expelled

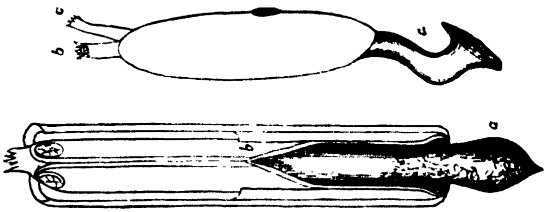


in a jet at its extremity, by a similar machinery. As the burrowing bivalve usually, if not always, dwells in the interior of the passage it has excavated, it is needful that there should be a communication with the external water, and hence a hole is always found extending to the surface of the material bored. The entering and departing currents keep this passage clear, a process which in mud or sand might seem at first not very easy of accomplishment. It is facilitated however by the faculty which the boring bivalves have of lengthening the siphonal tubes at will, and the degree to which this may be accomplished depends on the depth of the cavity which the species is accustomed to make. Yet since many particles of matter float, even in clear water, which from their form or other qualities might be hurtful to the delicate tissue of the viscera to be traversed, how is the entrance of these to be guarded against in an indiscriminating current? A beautiful contrivance is provided for this necessity. The margin of the entering siphon, and sometimes, though more rarely, of the ejecting one, is set round with a number of short tentacular processes, expanding like feathery leaves and varying indeed in their length, but the longest scarcely more than equalling half the diameter of the mouth of the tube.

In Pholas dactylus, this apparatus, which is here confined to the oral tube, is of peculiar beauty, forming a network of exquisite tracery, spread across the orifice through the interstices or meshes of which the current of entering water freely percolates, while they exclude all except the most minute floating atoms of extraneous matter. Thus admirably has the health and comfort of the lowly shell-fish been provided for, that spend their whole life buried in sepulchres of stone or sand!

The siphons, which are frequently connected or blended into one tube, are shorter, or even reduced to simple perforations, in those species which do not bury themselves so deeply; and in the oysters, mussels, and other genera that are superficially attached to submarine objects, the lobes of the mouth being completely distinct, the water is admitted at once to the branchiæ as soon as the animal opens its valves. The chief use of the shell is as a means of defence, and, to answer this purpose, it must naturally increase in solidity the more its owner is exposed to injury. The pholades and teredines which scoop

out their dwellings in stone or wood, and thus enjoy the protection of a retrenched camp, can do with a thin and brittle, or even with a mere rudimentary shell. The Solens, which at the least alarm are able to sink rapidly into the sand, and indeed very rarely quit the hole in which they are comfortably



Razor shells.
a foot. *b c* siphons.

ensconced, require no closely fitting valves; but the oysters, which have no external fortress to retire to, would be in a very bad predicament if they could not entirely conceal themselves within their thick shells, and keep them closed by strong muscular contraction. Even so, they are exposed to many persecutions, not only of man, or of the oyster-catcher who dexterously opens them with his strong beak, or of the star-fish who clutches them in a murderous embrace, but of a whole host of far more minute though not less formidable enemies. Small annelides, boring through the shell, attack them at all points, and though they endeavour to parry these assaults by fresh depositions of pearly matter, their strength is sorely taxed in the struggle. Soon parasitic sponges establish themselves in the holes pierced by the annelides, and eating deeper and deeper into the shell, at length entirely exhaust the poor victim, who sinking under his accumulated misfortunes gives up all further resistance, and, breathing his last, allows the enemy to penetrate into his gaping valves and to make a delicious meal of his remains.

The nervous system of the acephalous mollusca consists of three pair of ganglia, which send their filaments to the respective organs. The sense of touch appears to reside in every part of the body and of the mantle; that of hearing is lodged in the foot, and consists of two globular capsulæ inclosing a limpid fluid, and a calcareous body or otolithe suspended from the filaments of the auditory nerve, to which all its vibrations are instantly communicated.

The eyes, in those species where they have been detected, appear among the fringing processes of the margin as a number of glittering studs of metallic brilliancy, and though of a very simple structure, no doubt give their owner an agreeable impression of light, and in many cases a timely warning of approaching danger.

The whole construction, and generally the extremely restricted locomotion of the bivalves, tells us at once that they are unable to attack their prey, but must be satisfied with the food which the sea-currents carry to their mouth. Yet they have as little reason to complain as the equally slow or sessile polyps, bryozoa, and tunicata, for the waters of the ocean harbour such incalculable multitudes of microscopic animals and plants that their moderate appetite never remains long unsatisfied.

The same streams which aërate their blood also convey to their mouth all the food which they require.

The gasteropoda or snails are more highly organized than the bivalve molluscs. The body is more symmetrical, there is a greater distinction of parts, an obvious head, an evident tail; and, save that the body is without legs, we have often a considerable outward resemblance to some vertebrate animal, in the form of the body and in the expression of the countenance. For here is a well-formed face, surmounted by two, four, or six tentacula, commonly called horns, which either, as in the snail, carry each an eye at its summit, or, as is the case in most of the marine kinds, have an eye on a prominence at the base. But very few remain firmly attached to some foreign body, and make use of their rudimentary foot for no other purpose than for opening or closing the lid of their shell; generally a strong muscular disk attached to the ventral surface of the body (whence the whole order has derived its name of gasteropoda or stomach-footers) serves either as an instrument by means of which the animal can crawl, or, in rarer instances, is compressed into a muscular membrane, useful in swimming. Some of the gasteropoda are naked, while the majority are covered with a shell; some are formed for a terrestrial, others for an aquatic life; some are predacious, others herbivorous; and thus it may easily be imagined that their organization must offer numerous modifications to suit such various modes of life.

Although a superficial view might lead us to believe that

Providence had left the naked snails without any defence against their enemies, yet they have many means of escaping danger. The slug contracts itself into a heap, and throws from the pores of its body a thick slimy mucilage, which renders it difficult to make any impression upon its body, and is no doubt extremely offensive to many of its brute enemies. The crystal transparency of many of the marine species, which renders them almost undistinguishable from the clear sea water, screens them from numerous persecutions. Those that creep, find excellent places of concealment in the crevices of rocks, or among the branches of the madrepores; and the dorides, on contracting, cast off parts of their mantle, which they leave in possession of their hungry foe, while they themselves make their escape.

However different the form of the shell may be, its use is invariably the same, affording the soft-bodied animal a shield or retreat against external injuries. In this respect it is not uninteresting to remark that those species which inhabit the coasts, and are most exposed to the rolling of the waves, have thicker and stronger shells than those which live in greater depths, and that the freshwater molluscs have generally a much more delicate and fragile coat than those which live in the ocean.

The ianthinæ, however—who, unlike the generality of shell-bearing gasteropods, pass a great part of their lives floating on the water—form a remarkable exception to this rule, as in accordance with their mode of life their transparent shell is extremely light. Their foot also is provided with a vesicular organ which they are capable of inflating with air, and thus buoyed up 'like little wanton boys that swim on bladders' they often appear in vast shoals upon the surface of the seas. As soon as the winds ruffle the ocean, they immediately empty their air-cells, and sink down into a more tranquil element, and as a means of defence against their hungry foes they are capable of pouring out a purple liquid which tinges the water all around.

It is an invariable rule that, the greater the necessity of protection, the better has nature provided for the want. Thus most of the larger sea-snails, besides possessing a stone-hard dwelling, are also furnished at the extremity of the foot with an operculum, or calcareous lid, which fits like a door upon the en-

trance of their house, and closes it like a fortress against the outer world. But no animal exists that is safe against every attack, for the large sea-birds sometimes carry the ponderous snails, whose entrance they cannot force with their beaks, high up into the air, and let them fall upon the rocks, where they are dashed to pieces.

The limpets, slowly crawling over the stones under their shield-like cover, have no operculum to close its entrance, but their broad-soled foot renders a door perfectly unnecessary; for, acting like a powerful sucker, it clings with such tenacity to the rock, that it requires the introduction of a knife between the shell and the stone to detach them. It has been calculated that the larger species are thus able to produce a resistance equivalent to a weight of 150 lbs., which, considering the sharp angle of the shell, is more than sufficient to defy the strength of a man to raise them. It is also said that crows, and other birds, which endeavour to detach them for food, are sometimes caught by the points of their bills, and are held there until drowned by the advancing tide.

The land-snails have also no operculum, but before they fall into their winter-sleep, they close the mouth of their shells with a calcareous secretion which, stopping it up, entirely protects it from every external injury. In the centre is an extremely minute orifice, communicating with the lungs; and this minute hole, though not large enough to admit a drop of water, is of sufficient capacity for the passage of air. Not unfrequently, on removing this cover, a second or even a third similar one will be found within, forming additional safeguards against intrusion or the vicissitudes of temperature.

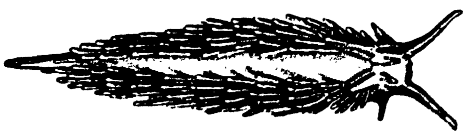
When the genial warmth of spring awakens the snail to a state of activity, its covering, now no longer needed, drops off, and the animal, protruding its horned head, sets out in quest of food, anxious to make amends for its long abstinence by feasting on the first tender leaves that fall in its way.

The respiratory organs of the gasteropoda are found to be constructed upon very various principles, according to the medium which they inhabit or the peculiarities of their mode of life. The common land-snails, as well as the freshwater snails, breathe air, which is received into a cavity lined with delicate network, analogous to the lungs of air-breathing animals, and

the freshwater kinds are obliged to rise to the surface every time they require to take in fresh air. Such a mode of aërating the blood would obviously be unsuited to marine gasteropoda which are consequently all furnished with branchiæ or gills differently placed. In the naked sea-slugs they expand freely in the water, like the tentacula of the sea anemone, and nothing can be more elegant than their forms or arrangement. In the glauci and scyllæa we see at each side of the elongated body long

Glaucus.

arms branching out into tufted filaments; while in the briarei a hundred furcated stems serve for the aëration of the blood. In the eolides they assume the shape of long riband-like lamellæ,

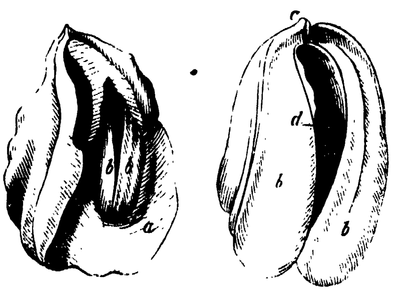


disposed in imbricated rows; in the dorides they form a wreath or garland round the lower intestinal aperture. But whatever their form, their structure is essentially the same, each tuft or lamella containing the ramifications of the branchial vessels, and effecting the oxygenisation of the blood by the extent of surface which they expose to the water.

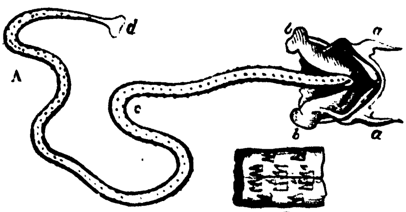
In the far more numerous gasteropoda provided with covered gills, we find the same variety of arrangement as in the nudibranchiate genera. In some they are placed on one side of the

body, under the deep fold of the mantle; in others they form a fringe round the margin of the body, between the edge of the mantle and the foot, while in all the spiral univalve molluscs whose shells enrich our cabinets, they are shaped like the teeth of a comb, and placed in a large hollow chamber in the animal, communicating with the surface by a wide slit, through which the water finds free access to the gills.

The digestive apparatus of the gasteropoda offers many points of considerable interest. The mouth, in many species, is furnished with sharp and strong teeth, as for instance in the tritonia, where it is armed with two cutting blades (*b b*), resembling in every respect a pair of strong curved shears, which, set in motion by powerful muscular fibres, are so efficacious that few animal structures can resist their edge. The lips which are placed in front of these teeth are strong and very flexible, forming a muscular tube, by means of which the food is seized and brought within the power of its formidable jaws, and then the divided morsels, being seized by the horny teeth which invest the tongue (*d*), are conveyed into the œsophagus.



In others the process of digestion is facilitated by strong bony gizzards, which bruise the food in its passage into the stomach; and in others the tongue is armed with spinous processes obviously intended to assist in the preparation of the food. That of the limpet, which is three times the length of the body, is supported by two cartilaginous pieces (*b b*) placed on each side of its root. From these arise strong and short muscles, which wield the organ. The surface of this singular tongue, a magnified view of which is given at B, is armed with minute though

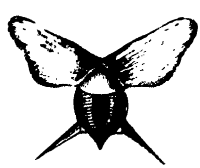


A, limpet's tongue. B, portion magnified.

strong teeth, placed in transverse rows, and arranged in three series; each central group consists of four spines, while those on the sides contain but two apiece. In the upper part of the circumference of the mouth, we find a semi-circular, horny plate, resembling an upper jaw, and the tongue, by triturating the food against this, gradually reduces substances, however hard. On opening the limpet the tongue is found doubled upon itself, and folded in a spiral manner beneath the viscera.

Although they are deprived of all higher instincts, yet we find among the gasteropoda a few examples of concealment under extraneous objects, which remind us of the masks and artifices frequently employed by the insects and the crustaceans. The agglutinating top (trochus agglutinans) covers itself with small stones and fragments of shells, and, thus shielded from the view, escapes the voracity of many an enemy but little suspecting the savoury morsel hidden under the little mound of rubbish which he disdainfully passes by. In animals which are only provided with passive means of defence, we may naturally expect a considerable degree of caution, and in this respect the gasteropoda might give many useful lessons to man. See how carefully our garden-snail protrudes her tentacles, as far as possible, to sound every obstacle in her way before she drags herself farther along, and how quickly she withdraws into her shell at the least symptom of danger. What an example to so many of us that leap before they look, and frequently break their necks in the fall.

While the snails, whether terrestrial or marine, are proverbially slow, the pteropods, or wing-footers, swimming by the aid of two muscular expansions resembling fins, and attached to the opposite sides of the neck, are remarkable for the velocity of their movements. They have no disk to walk upon like the gasteropods, but resemble them by the possession of a head distinct from the rest of the body, which some, like the hyaleas and cleodoras, conceal in a thin transparent or translucent shell; while others, like the blue and violet clios, beautifully variegated with light red spots, are perfectly naked. They are met with in all seas under the equator, as well as in the vicinity of the polar



Venus's Chariot.
(Hyalea Globulosa.)

circle; and, being eminently constructed for a sea life, never approach the shore. They are all, moreover, nocturnal or crepuscular, voyagers agreeing that they are never to be seen during a clear day, when the sun shines brightly; but towards five o'clock in the evening, when the weather is cloudy, two or three species begin to make their appearance at the surface of the water. Thence onwards their numbers increase, but each species seems to have its appropriate hour, or rather its appropriate degrees of darkness. As the night sets in, all the smaller species gradually disappear, as do the large ones a little later; and towards midnight a few stragglers only of different kinds are to be met with. At sunrise not a single pteropod is to be seen, either at the surface or at any depth to which the eye can penetrate. They swim in a very peculiar manner. Their cephalic fins are only able to support them by a constant repetition of rapid movements, resembling those of the wings of a butterfly. These fins are kept in motion continually; and, according to the direction of their stroke, the animal advances horizontally, or mounts or descends, the body remaining all the time either in a vertical position or slightly inclined. If, while they are thus in motion, the appearance of any strange body causes them alarm, their wings fold upon their bodies, or in some species are entirely withdrawn into their shell, and the animal sinks rapidly to a greater depth. They seize their prey partly like the Pneumodermas, with tentacular arms; partly like the Clios, by means of six conical appendages to the head, which, when fully expanded, form a kind of star round the mouth, and when strongly magnified, exhibit a truly admirable structure, and indeed quite unparalleled in the animal creation. For each of these small cones is furnished with about *three thousand* prehensile organs, consisting of a transparent sheath (*a*) enclosing a central body composed of a stem terminated by a kind of tuft, which last can be protruded at times beyond the margin of the sheath. When viewed laterally, it is apparent that this central body consists of several filaments or tubes, every one of which (*b*) expands at its extremity into a

a, prehensile organ, magnified 300 diameters.
b, isolated sucking disk, magnified 900 diameters.

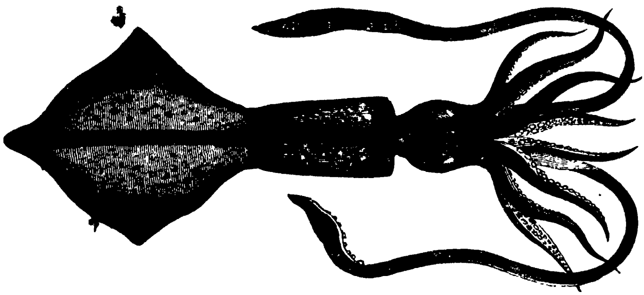
dilated portion terminated by a little disk, and about *twenty* of these are enclosed in each sheath. Thus every one of these little creatures, which often crowd the surface of the Polar Seas in incalculable numbers, and form the chief nourishment of the huge whale, is furnished with no less than *three hundred and sixty-thousand* sucking disks—a magnificent profusion, which may well be called one of the miracles of Nature! But we have not yet done with the Clio, for on opening its mouth we shall find new occasions to admire the care that has been bestowed upon its organisation. On each side of the buccal aperture projects a hard shining substance, which is not a single tooth, as it might appear to the naked eye, but rather a dental apparatus (a), consisting of a bundle of about thirty gold-coloured crooked, stiff, and sharp hooks derived from a common base, and forming a pair of lateral jaws, which, when protruded, seize their prey like a couple of long tenacious combs. A tongue-like organ (d) situated in the cavity of the mouth and studded with about eight hundred hooklets assists their functions, and facilitates the propulsion of the food into the stomach.

Clio Borealis.

a dental apparatus, and *b c* single teeth, magnified diameters, *d* lateral view of free portion of tongue magnified 130 diameters.

As the sea-urchins are the first among the radiata, thus the cuttle-fish are the most perfect specimens of the molluscar type. These remarkable creatures consist of two distinct parts:—the body, which in form of a sack, open to the front, encloses the branchiæ and digestive organs; and the well-developed head, provided with a pair of sharp-sighted eyes, and crowned with a ring of feet, arms, or feelers.

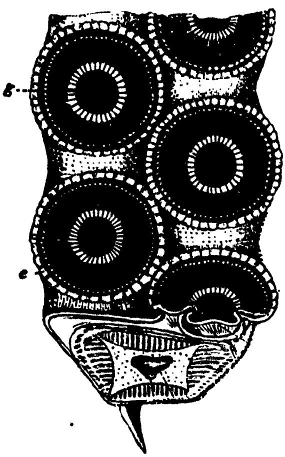
All the cephalopods are marine animals, and breathe through branchiæ or gills. These organs are concealed under the mouth



Cuttle-fish. (Sepia.)

in a cave or hollow, which alternately expands and contracts, and communicates by two openings with the outer world. The one, in form of a slit, serves to receive the water; the other, which is tubular, is used for its expulsion.

According to the different number of their branchiæ, the cephalopods are divided into two natural groups, one with four, the other with two gills. The former, which abounded in the primitive ocean, is reduced in the present seas to the single genus of the Nautili; the latter, which is far more numerous, is subdivided into the two great families of the octopods and the decapods; the former having only eight sessile feet, the latter ten, two of which are considerably longer than the rest. The feet are studded on the inner surface with acetabula or suckers, either sessile or pedunculated. The sessile cups of the octopods are muscular disks with a soft and tumid margin (*e*), and a circular aperture in the centre (*g*), opening into a cavity which widens as it descends, and contains a cone of soft substance rising from its bottom like the piston of a syringe. When the sucker is applied to a surface for the purpose of adhesion, the piston, having previously been raised so as to fill the



Section of an Arm and Suckers of a Poulp.

cavity, is retracted so as to produce a vacuum; and such is the muscular force of the animal that it is easier to tear away the substance of the limb than to release it from its attachments.

Arms and Tentacles of an Onychoteuthis.

In the decapods, which are not confined to the coasts like the eight-footed poulps, but have to contend with the agile, slippery, and mucus-clad fishes, we find the disks provided with a sharp hook fixed in the centre, and to add to their efficacy they are mounted on stalks movable in every direction. Let the reader picture to himself these weapons, clustered at the expanded terminations of the tentacles (*f*), and arranged in a double alternate series along the whole internal surface of the eight muscular feet (*c*), and he will have some idea of the formidable nature of the Onychoteuthis.

Besides the hooked acetabula, a cluster of small simple unarmed suckers may be observed at the base of the expanded part. These add greatly to the animal's prehensile powers, for when they are applied to one another (*e*), the tentacles are firmly locked together at that point, and the united strength of both the elongated peduncles can be applied to drag towards the mouth any resisting object which has been grappled by the terminal hooks. There is no mechanical contrivance which surpasses this admirable structure.

The size of the arms and the arrangement of the suckers differ considerably in the various species. In the octopods, which generally lead a more sedentary creeping life, and clinging to stones seize the passing prey, the arms, in ac-

cordance with their wants, are, with rare exceptions, longer, more muscular, and stronger than in the actively-swimming decapods, where the two elongated tentacles or peduncles are the chief organs of prehension. In some species we find the arms distinct —in others they are united by a membrane. Some have a double row of suckers on each arm, others four rows, others again but one.

So wonderful are the variations which Nature, that consummate artist, plays upon a single theme—so inexhaustible are the modifications she introduces into the formation of numerous species, all constructed upon the same fundamental plan, and all equally perfect in their kind! Besides their arms, by help of which the cephalopods either swim or creep, the forcible expulsion of the water through the air-tube serves them as a means of locomotion in a backward direction. By those which have an elongated body and comparatively strong muscles, this movement is performed with such violence that they shoot like arrows through the water, or, even like the flying-fish, perform a long curve through the air, so as not seldom to bolt right over a sailing ship, like a sportsman over a five-barred gate. Finally, the fin-like expansion of their mantle, which in some species runs along the sides of the body, and in others forms a kind of terminal paddle, renders the nimble decapods good service in propelling them forwards in the water.

When a cephalopod has got hold of a fish or crab, the arms, by sucking or hooking, instantly convey the luckless animal to the mouth, where it is pitilessly crushed by two powerful horny or calcareous jaws, fitting one over the other like the mandibles of a tortoise. It might be supposed that the cephalopods, by their swiftness, their arms, and their powerful jaws, were sufficiently provided with the means of attack or defence; but Nature has besides favoured most of them with a remarkable secretory organ, producing a black fluid and opening into the air-tube. When pursued by its enemies, the animal ejects a sufficient quantity of this inky liquid to form a thick cloud in the water, which serves to conceal it from its foe.

The enormous numbers and prodigious variety of the molluscs are sufficient proofs of their importance in the economy of Nature. The terrestrial snails are disseminated in more than 2,200 species over the surface of the globe; the slimy slugs infest

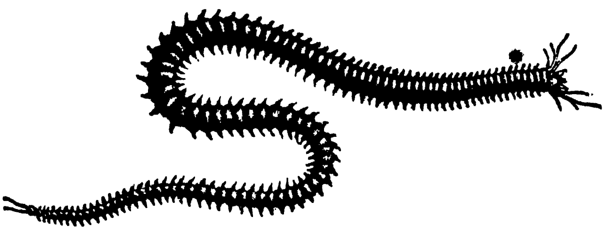
every field and garden; hosts of Limnaeæ people every pond; and the sea absolutely swarms with molluscs which either graze upon the submarine pastures, or, warring upon each other, serve in their turn as food to countless enemies. Animals generally so defenceless, and exposed to so many persecutions, must necessarily multiply in an analogous ratio. The calamary produces from forty to fifty thousand eggs in a single season; a thousand garden slugs are capable of multiplying in one year to the number of five hundred millions; and the oyster lays several millions of eggs in the course of the summer. The germs of a new generation become more numerous as the means of defence are smaller; and thus we find the sedentary and helpless mussels more prolific than the cephalopods, which have been so admirably equipped both for defensive strategy and for offensive warfare.

CHAPTER XX.

WORMS.

Are they in reality so helpless as is commonly supposed?—Beauty of the Free Marine Annelides—Their Mode of Life—Tubicolar Worms—Leeches—Earth-worms—Nemerta Gigantea—Rotifera—Their Complex Organisation and their Habits.

Worms are commonly supposed to be the very images of helplessness and degradation—their name is often used to express all that is abject and low; but a closer inspection soon convinces us that their organisation is far too wonderful to justify contempt, and that, like every other work of their Divine Maker, they are beautiful and perfect in their kind. Many of them, no doubt, are so lowly placed in the scale of organic creation, that they can only live, as parasites, upon the blood or juices of other animals; in many the structure of the body is reduced to very



Nereis.

simple elements, such as befit an indolent and inert existence; but the higher members of the class, the vagrant marine annelides, are richly provided with all the means of leading a life of activity and enjoyment.

A red blood circulates in their veins; thousands of muscles direct the serpentine movements of their body, which frequently consists of several hundred segments or rings; and each ring

has its delicately-formed branchiæ (*f*), and its bristly feet (*a b*), serving both for locomotion, and for clasping their prey in a deadly embrace. Clothed in robes of metallic brilliancy, these beautiful worms of the ocean, to whom the naturalists have given the most flattering names of Greek mythology — Nereis, Euphrosyne, Eunice, Alciopa,— glide through the crevices of submarine rocks, or conceal themselves among the water-plants, or in the mud or sand at the bottom of the sea. Here they lie in wait for their prey, ready, like the larger snakes of the dry land, to dart forth suddenly upon the first unfortunate crustacean or naked mollusc that heedlessly swims by: but their care must be great not to be led too far away by the ardour of the chase, for the sea swarms with their enemies, and woe to the annelide that falls into the grasp of the formidable cuttle-fish, or comes within the reach of the ferocious crab, or meets the eye of the greedy eel—for, once in the power of these inexorable enemies, it must bid farewell to life!

Fo[illegible] an Annelide.

Besides the erratic annelides, which must be considered as the most perfect of their class, the sea contains a large number of sedentary worms, leading a solitary hermit-life, in tubes formed by the mucus which is secreted by the skin, and which, while hardening, commonly agglutinates together fragments of shells and sand. Some of these sheaths are of extreme tenuity, others as tough as thick leather, and many possess very considerable hardness, being composed, in great proportion, of carbonate of lime, like the shells of molluscs. As these tubicolar annelides lead so very different a life from that of their roaming relations, their internal structure may naturally be supposed to be very different: for where is the living being whose organisation does not perfectly harmonise with his wants? Thus we have here no bristling feet, or lateral respiratory appendages; but instead of these organs, which in this case would have been perfectly useless, we find the head surmounted by a beautiful crown of feathery tentacula, which equally serve for breathing and the seizure of

a passing prey. Completely closed at the inferior extremity, the tube shows us, at its upper end, a round opening—the only window through which our anchorite can peep into the world, seize his food, and refresh his blood by exposing the beautiful

Terebella Conchilega. Serpula Contortuplicata. Sabella Unispira. Sabella Alveolaria.

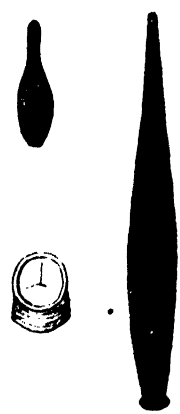
plumes of his floating branchiæ to the vivifying influence of the water.

But how is the safety of these beautiful little creatures, incapable as they are of flight, provided for—how do they manage to escape their enemies? Mark a serpula expanding its gorgeous coronet in the water, and the question will soon be answered; for at the least shock, at the least vibration, you will see the splendid tufts suddenly contract, and dive with the rapidity of lightning into their stronghold, shutting at the same time the

door after them, a small round richly-coloured lid, exactly fitting the orifice, and hermetically closing it against all intruders.

The tubicular annelides (such as the terebellæ, serpulæ, and sabellæ) have the greatest resemblance in their mode of life with the sedentary polypes, the flustræ, and the barnacles; for all these animals, firmly linked to the spot on which they live, depend for their food upon the prey which the sea, their bounteous mother, wafts within their grasp, and all, at the approach of danger, shrink within the hollow of their shells or cells. Yet how different is their internal structure, as they not only belong to different families of one class, but even to totally different classes of animals! Thus we find a prodigal multiplicity of form in creatures, whose sensations and enjoyments seem to be entirely on a level, for it has been the Creator's will that the beauteous variety of our flower-beds should adorn the submarine gardens of the crystal deep.

The sweet water of the ponds and rivulets is far less abundant in annelides than the briny sea. Here the small naïdes glide swiftly about, by means of their long bristly feet, or attach themselves to aquatic plants; here also is the seat of the water-leeches, a peculiar genus of worms, provided with a sucker at both ends of the body, serving them both for locomotion and for attaching themselves to their prey.



Leeches (medicinalis.)

The mouth, situated in the middle of the cavity of the anterior sucker, is as admirable a piece of mechanism as that of the sea-urchin. Three jaws are disposed around it in such a manner, that their edges, forming an obtuse angle, meet in the centre like the radii of a circle. Each jaw has two rows of minute teeth at its edge, so as to resemble a small saw, and is imbedded at its base in a layer of muscle, by the action of which it is worked in such a manner as to cut into the skin—and thus the well-known triradiate form of the leech-bite is occasioned. The lacerated character of the wound is very favourable to the flow of blood, which is still further encouraged by the action of the sucker.

Armed with a weapon so beautifully adapted to their wants, the leeches not only attack the frogs and fishes, on whose fluids

they chiefly subsist, but also the quadrupeds—horses, cattle, wild animals—that come to slake their thirst or to bathe in the pools which they infest. But they, in their turn, have to encounter a host of enemies: the large water-beetles and their larvæ destroy them by myriads; several of the fishes esteem them as dainty morsels, and numerous water-birds and waders rejoice in their capture.

While the land-leech besets the traveller in the rising grounds of Ceylon, or on the lower slopes of the Himalaya, and is detested as the greatest plague to be encountered in the humid forests, the medicinal leech of Europe renders, as is well known, such signal services as a remedial agent in inflammatory diseases, that millions are annually used. This vast consumption has already exhausted numerous lakes and ponds, in which it formerly abounded; so that while a few years since the hospitals of Germany, France, and Great Britain drew their chief supply from the Hungarian marshes, they now receive their leeches from the lagunes of the Volga and the Don.

On the dry land the chief representatives of the annelides are the earthworms, which, piercing and traversing the ground in every direction, subsist on roots, woody fibres, animal matter, and other organised substances. Though small and despised creatures, the part they perform in the operations of Nature is highly important; for insinuating their pointed head between the particles of the earth like a wedge, and then drawing forwards the hinder parts by a shortening of the body, they forcibly dilate the passage into which the head has been already thrust, and thus by the united labours of myriads the earth is lightened, and vegetation thereby wonderfully assisted.

Thus the obscure earthworm renders indirectly considerable services to man, and giving a kind of under-tillage to the land, performs below ground the same office that the spade performs for the garden, and the plough for arable land. Compared with the marine annelides, the organization of the earthworm seems but rude and imperfect, as it has neither the numerous feet of the elegantly-swimming nereids, nor the magnificent crown of the serpulæ, and occupies about the same rank as the lob-worm, so common on our coasts, where it is dug for by the fishermen as bait. Along the rings of the middle part of the lob-worm's body are gills of an arborescent form, corresponding with the

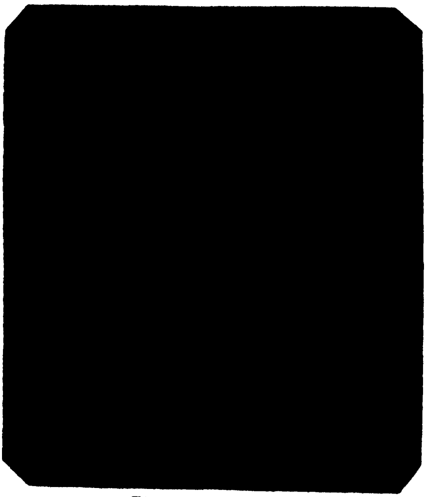
semi-aquatic life of the animal, while the earthworm respires through internal pulmonary vesicles. Both worms have neither the eyes nor the antennæ nor the well-armed jaws which distinguish the higher orders of the class, and are thus no better than plebeians in the little commonwealth of the annelides. The turbellariæ and the intestinal worms, however, stand on a still lower step of organic development; for the former, which are partly, like the nemertinæ, of an elongated wormlike form of body, partly of a flattened shape, like the planariæ, show no trace of segments or rings, and being entirely deprived of peculiar respiratory organs, breathe merely through the entire outward surface of their naked bodies.

The great band-worm (Nemertes gigas) is one of the most remarkable examples of this low type of annelism. It is from thirty to forty feet long, about half an inch broad, flat like a ribbon, of brown or violet colour, and smooth and shining like lackered leather. Among the loose boulders or in the crevices of submerged rocks, where it feasts on minute shells and other tiny creatures of the deep, this gigantic sea-worm forms a thousand seemingly inextricable knots, which it is constantly unravelling and tying. When after having devoured all the food within its reach, or from some other cause, it desires to shift its quarters, it stretches out a long dark-coloured ribbon, surmounted by a head like that of a snake, but without its wide mouth or dangerous fangs. The eye of the observer detects no muscular contraction, sees no apparent cause or instrument of locomotion; but the microscope, the mighty revealer of hidden wonders, shows him that the innumerable vibratory ciliæ with which the whole body of the nemertes is covered cause it to glide along. The creature hesitates, tries here and there, until at last, and often at a distance of fifteen or twenty feet, it finds a stone to its taste, whereupon it slowly unrolls its length, to convey itself to its new resting-place or pasture-ground; and while the entangled folds are unravelling themselves at one end, they form a new gordian-knot at the other. Thus, in spite of the extreme simplicity of its organisation, the band-worm is fully equipped with all the means of existence, and the eye of its All-seeing Maker directs it, though blind, to its food.

In spite of their abject mode of life, the intestinal worms must be reckoned in many respects among the great marvels of

creation. We wonder at the immense variety of animals which people the abounding land or the teeming waters; but our admiration at this exuberance of life rises to a still higher point, when we consider that this visible world of animated beings encloses another world of equally sensitive creatures, which hidden from the eye lead a parasitic existence in their intestinal recesses. Worms of the most various forms and sizes are found within the bodies of all vertebrated animals, and even in many molluscs and insects; and though above 1,400 species have already been described, yet there can be no doubt that a far greater number still remains undiscovered, as comparatively but few quadrupeds, birds, or fishes have hitherto been accurately dissected; and as far as our observation reaches, every genus or even every species of the vertebrate animals has been found to possess its own peculiar parasitical worms, each of whom again selects some favourite organ for his abode.

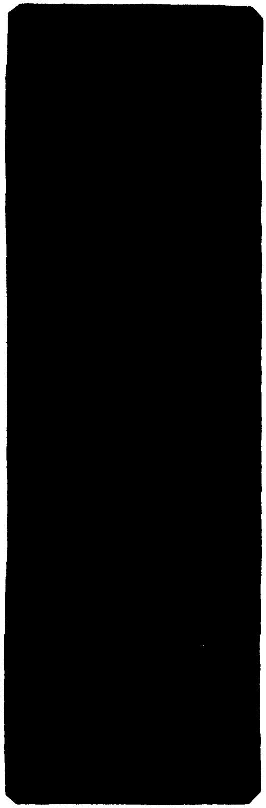
If size alone were a criterion of classification, the Rotifera would have to be ranked among the Infusoria, as they are scarcely discernible by the naked eye; but a more complicated organisation separates them widely from these lowest members of the animal kingdom, and assigns them a place among the worms. Their most striking external character are the rotatory organs or ciliary wheels with which their head is surmounted, and whose vibratory motions, whirling the water about in swift circles or eddies, engulf in a fatal vortex the microscopic animals or plants on which they feed, or enable them to swim from place to place. The great transparency of these curious little animals permits their general structure to be easily recognised. The mouth lies between the wheels, and



Ptygura melicerta.
1. partially expanded, 2. completely expanded, the cilia in action causing currents indicated by the arrows, 3, contracted.

when once an unfortunate animalcule has been driven into its gaping portals, it is presently crushed between a pair of formidable sharp-toothed jaws, which are constantly in motion, whether the animal is taking food or not. The aliment, chewed or ground by this lively apparatus, passes into a slender canal or tubular stomach, surrounded by a cushion-like mass of cells, commonly coloured with the hue of the food, and therefore concluded to be connected with the digestive system.

The rotifera are either naked, or covered with a gelatinous or horny sheath; and many inhabit a tube formed by themselves, attached by its lower end to some water-plant, and open at the summit, from which the animal protrudes when it would exercise its active instincts, and into which it retires for repose from labour, or for refuge from alarm. The majority, however, have a single or furcated foot, which is often capable of contraction by a set of telescopic sheathings or false joints, and by means of which they are enabled to secure a hold of the minute stems of water-plants. This is their ordinary position, when keeping their wheels in action for a supply of food or of water; but they have no difficulty in letting go their hold, and either creeping along like a leech, by alternate contractions and extensions, or swimming away in search of a new attachment.



Philodina roseola.

pouch, *e* anal orifice.

From the neck projects a telescopic spur or tube (*a*), supposed to be an organ of respiration; and just below this are seen two minute red specks, which are the animal's eyes—rudimentary indeed, and probably endowed with no more of visual power than a slight consciousness of the stimulus of light.

Some of the rotifera are inhabitants of salt water only, but by far the larger proportion are found in collections of fresh water

—as, for instance, in the little pools left after rain, in the hollows of the lead with which the tops of houses are partly covered, or in cisterns which are not beneath roofs, or otherwise covered over. Some species flourish attached to damp moss; others inhabit the snows of the Alps, or the leaf-cells of Sphagnum, or the intestinal tube of the earthworm, or even the interior of the likewise microscopical Volvox globator, devouring the colonies that form within the cavity of its tiny globe, and replacing them, cuckoo-like, with their own eggs. Several hundred species of these interesting little animals have already been discovered, and *there can be no doubt of the existence of a vast number of still* unknown forms.

Their tenacity of life is most remarkable, for they can be kept in a state of complete dryness for any length of time, and will yet revive very speedily upon being moistened. This fact, taken in connection with that extraordinary rate of increase which characterises all microscopical animals and plants (according to the estimate of Professor Ehrenberg, nearly 17,000,000 may be produced within twenty-four days from a single rotifer), removes all difficulty in accounting for the extent of their diffusion, and for their occurrence in incalculable numbers in situations where a few days previously none were known to exist: for their entire bodies may be wafted in a dry state, by the atmosphere, from place to place, and their return to a state of active life, after a desiccation of unlimited duration, may take place whenever they meet with the requisite conditions—moisture, warmth, and food. Thus the insignificant Rotifera, the marvels of whose organisation it requires the microscope to reveal, fully exemplify the truth of the fine remark of Pliny, that Nature is nowhere more admirable than in her smallest productions!

CHAPTER XXI.

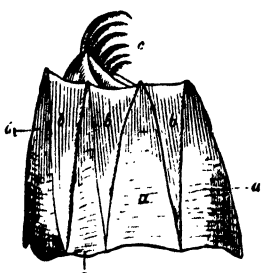
CRUSTACEANS.

Cirripedes — Barnacles and Acorn-shells — Edriophthalmia — Decapoda — Their Branchial Apparatus—Legs and Digestive Organs—Moulting Process—Metamorphoses—Enemies of the Crustaceans—Means of Defence, and Offensive Weapons—The Birgus—Pinnotheres—Paguri—Migratory Instinct of the Land-crabs.

As the dry land teems with infinite forms of insects, so the seas, from the equator to the poles, are peopled with legions of crustaceans. Though all constructed on the same fundamental plan, yet the various subdivisions of this vast and important class differ so much in outward appearance, and their organization is so considerably modified according to their various habits, that even the eye of science has been long unable to distinguish the real nature of several of their lowest forms.

Barnacle.

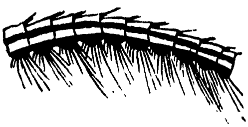
Thus the Barnacles, which frequently attach themselves in such vast numbers to ships' bottoms as materially to obstruct their way, and the Acorn-shells, which cover in scurfy patches the surface of exposed rocks, often lining the coast for miles and miles, were formerly reckoned among the molluscs, until a better knowledge of their early stages of development proved them to be real crustaceans, distant relations of the crab or lobster, whom when full-grown they so little resemble.



Acorn-shell,
a first series of compartments,
b second series, *c* cirri.

While in the first stage of infancy, these ambiguous creatures

lead the vagrant life of the juvenile oyster or adolescent sponge, bounding nimbly along by the simultaneous stroke of their numerous legs, and possessed of open eyes to pilot their course through the waters; but, when once fixed, they remain attached for the remainder of their lives, and then their structure undergoes a most remarkable change. The shell is gradually formed, the eyes are cast away as being no longer needed, and the now useless feet are converted into extremely useful arms or cirri, resembling a plume of purple feathers. These cirri are constantly in motion as long as they are bathed in water, projecting outwards, and expanding into an oval concave net—then retracting inwards, and closing upon whatever may have come within their reach. They are so judiciously placed that any small matter which becomes entangled within them can rarely escape, and finds a ready passage to the mouth. The currents produced in the water by their perpetual motion serve also to aërate the blood, so that these delicate organs act both as gills and as prehensile arms. In spite of their sessile condition, the Cirripeds, as these curious animals are named, have not been left without protection against hostile attacks; for at the approach of danger they shrink within their shell, and close its orifice against a host of hungry intruders. Living above low-water-mark, the Acorn-shells are necessarily exposed to the air for several hours during the recess of every tide—a proof of their power to resist ungenial circumstances, and of the beautiful harmony of their organisation with the mode of life which has been marked out for them in the plan of Creation.



A part of one of the arm considerably magnified.

While the Cirripeds grasp, as in a living net, any minute creatures that may be roving withing their reach, the *Siphonostomata* (Fish-lice, lerneæ) lead a parasitic life chiefly upon fishes, sucking their juices with a bloodthirsty proboscis. The fish-lice wander about freely on the body of their victims, as grazing animals on their pasture-grounds; while the Lerneæ, after having, like the barnacles, led a vagrant life in their first youth, remain ever after clinging to the spot on which they once have settled.

Both are blind, and have but an indistinct head; while the

numerous families and species of the entomostraca and branchiopoda, their next superiors in rank, are generally well provided with organs of vision.

Some of these minute animals, which are generally active in their movements, have no special respiratory organs, the whole tegumentary surface being made to supply their place; while in others the foliaceous legs perform the office of gills, the skin or covering of these limbs being so delicate that it admits the vessels which ramify over it to have sufficient contact with the water to allow of the perfect aëration of the blood. Thus these little creatures may be said to breathe through their legs and arms, which may be seen in constant motion playing through the fluid, and causing a constant flow of new particles to the exposed surface of the bloodvessels.

On a higher stage of crustacean life we find the Edriophthalmia, whose thorax and abdomen are distinctly composed of articulated segments, or rings, which is not the case in the above-mentioned orders. Here the legs no longer serve as gills, but for the ordinary purposes of locomotion; certain portions of the extremities, however, are modified in their structure so as to perform the functions of respiratory organs. To this order belong, among others, the nimble Sandhoppers, who, when disturbed in their privacy, bound into the air by thousands from the wet sea-sand; the Cyami, or Whale-lice, which frequently feed by thousands on the skin of the huge cetaceans; and the terrestrial Onisci, or Wood-lice, which, generally leading a life of concealment under stones, in walls, in cellars, or in the cavities of decaying trees, come forth from their retreat only in wet and moist weather.

Sandhopper.

Thus, rising step by step, we come at length to the most perfect type of crustacean life—to the Thoracostraca, whose eyes are moveable and fixed on stalks, whose head and thorax are covered with a carapace or shield, and whose abdomen only retains the annular structure.

This highest order of the crustaceans is again subdivided into the Stomatopoda, with external branchiæ and feet approaching the mouth; and the Decapoda, which are either long-tailed, like the shrimp or lobster, or short-tailed, like the crab. In the

Decapoda the branchiæ are enclosed in two chambers, situated one at each side of the under-surface of the carapace or broad shelly plate which covers the back of the animal. Each of these chambers is provided with two openings—one in front near the jaws, the other behind. In the long-tailed species the posterior opening is a wide slit at the basis of the feet; in the short-tailed kinds a small transverse aperture, before the first pair of feet. By means of this formation—which, from its limiting the amount of evaporation, prevents the drying of the branchiæ—the crabs, like those fishes that are provided with a narrow opening to their gill-covers, are enabled to exist much longer out of the water than the lobsters. Some of them even live habitually out of water; and, to fit them for this terrestrial life, their respiratory caverns are provided with folds and lacunæ, capable of serving as reservoirs of a certain quantity of water, or with a spongy membrane equally well calculated to store up the fluid necessary to keep the organs of respiration in the state of humidity necessary to enable them to perform their functions. It is well known, too, that the land-crabs never remove far from damp and shady situations, where the moisture of the sultry air reduces evaporation to its lowest degree. While in fishes the water that serves for respiration flows from the front backwards, so as not to impede their motions, the stream of water traversing the gills of the crustaceans is made to flow from behind forwards, and thus harmonises perfectly with their retrograde or sidelong movements. So wonderfully has the anatomical structure of these animals, like that of all other living things, been suited to their peculiar mode of life!

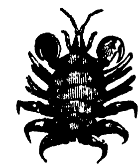
The same beautiful adaptation of means to end strikes us on examining the locomotive apparatus of the various tribes of crustaceans. Thus in the Gecarcini or Land-crabs, and particularly in the Ocypoda or Sand-crabs, which inhabit the seashores of warm climates in both hemispheres, the legs are extremely strong in comparison to the weight of the body, and consequently able to carry it along with great rapidity. In the burrowing Hippidæ they are short, thick, and awkward, but well formed for working in the sand, like those of the mole. In the Sea-spiders we find them extremely elongated, so that the animal swims badly, and is a very indifferent pedestrian. But its mode of life, which is strictly confined to the shallow waters of the littoral zone—where,

concealed among the seaweeds, it wages war with annelides, planarias, and small molluscs—requires no very active movements, and they answer admirably either as holdfasts among the cliffs and boulders, or for seizing their prey in the deeper crevices of the rocks.

In the Portuni or true Sea-crabs, finally, we find the hind pair of legs flattened like oars, so that they would cut but a sorry figure on land, but are all the better able to row about in their congenial element.

The comparatively short and weak though well-formed legs of the lobster, and of the allied species of long-tailed decapods, can evidently bear them along but slowly when they attempt to crawl. But the long flattened tail of these animals, expanding laterally like a fin, serves, by its vertical strokes, to propel them so rapidly through the water that the lobster makes leaps of twenty feet at one single bound, and the shrimp is seen to dart about in its native element with a swiftness similar to that of the gnat or dragonfly in the lighter atmosphere.

The elongated hind-legs of the sandhoppers, contracted while at rest, enable them, when suddenly extended, to emulate the leap of the flea or the bound of the podura; while the feet of the Whale-lice, or Cyami, are armed with powerful claws, which are evidently necessary, to prevent their being washed away during the rapid evolutions of their enormous victims. In the terrestrial species of the Oniscidæ, popularly known by the name of Wood-lice, the large number of the feet makes up for their smallness; in the aquatic or natatorial members of the family, the last pair of legs and the last shieldlike segment of the abdomen form a large fin; while the short feet of the parasitical species, such as the Bopyrus Squillarum, which passes its life under the tail of the shrimp, is provided with strong claws, for the purpose of securing a firm attachment to their living prey.



Whale-Louse (Cyamus)

The digestive apparatus of the crustaceans is also most admirably modified, according to the respective wants of their various tribes. Those which, in their state of perfect growth, live almost invariably attached to their prey, without executing any other motions than such as are performed by the latter, are

provided with a trunk or cylindrical tube of variable length, adapted for sucking, and in the interior of which are lodged the mandibles, prolonged so much that they form two slender and pointed processes, the extremities of which serve as a lancet. Thus these fortunate parasites, who never know what it is to want a meal, are enabled to tap the vessels of their victims, and to quaff, without any further trouble, the rich juices they afford!

But in the higher orders of crustaceans, whose food is generally of a solid and not easily digestible nature, the structure of the oral apparatus is very different. The mouth is here furnished with at least eight pieces or pairs of jaws, which pass the food through an extremely short gullet into a membranous stomach of considerable size. This stomach is rendered curious by having within certain cartilaginous appendages, to which strong grinding-teeth are attached. These are placed at the pyloric extremity or outlet of the stomach, so that the aliment, after being subjected to the action of the jaws, is again more perfectly chewed by the stomach-teeth before entering the digestive tube, where it is exposed to the action of the biliary fluid of the liver. The different pieces composing the masticatory apparatus of the stomach vary considerably in the different genera, and even in the several species of the same genus; but in every case they are always singularly in harmony with the kind of food taken, and the general habits of the animal.

The solid shell of the higher crustaceans completely encases their body like a coat of mail. Unlike that of the sea-urchins, which is formed of a multitude of small plates, constantly increasing in diameter by the deposition of fresh calcareous matter on their edges, and keeping pace with the growth of the animal, it consists but of one piece, and is consequently incapable of extension. Thus the lobster or the crab, after having once attained their perfect form, would have been obliged ever after to endure the confinement of a narrow garb, had not Providence endowed them with the faculty of casting their shell from time to time, and thus providing themselves with a new and more convenient tegument. A few days of fasting and sickness precede the operation, during which the carapace becomes loosened from the skin to which it adhered, and immediately begins to secrete a new one—soft and membranous at first, but soon be-

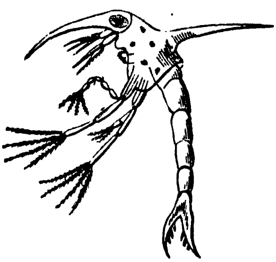
coming harder and harder, and finally completely calcareous. In this way the animal before long finds itself free from all connection with its old envelope, and it has only to make its escape. This last operation is announced by symptoms of inquietude. The creature rubs its legs one against the other, and then, throwing itself upon its back, begins to shake itself, and puffs itself out so as to tear the membrane which connects the carapace with the abdomen, and to raise the carapace itself. After sundry intervals of rest and agitation, of shorter or longer duration, the carapace is raised completely, and the animal extricates its eyes, its head, and its antennæ. The operation of freeing its extremities appears to be the most difficult, and would even be impossible, did not the covering of these parts split longitudinally. The abdomen is the last division of the body which clears itself of the old envelope. It may easily be supposed that, after such a violent struggle for freedom, the lobster is not a little exhausted. Feeling his weakness, and aware of the very insufficient protection afforded him by his soft covering, which requires a day or two to convert itself into a firm calcareous shell similar to the one which has just been cast off, he prudently retires from all society, until he feels himself able to meet his old friends again on terms of equality, for he well knows how inclined they are to bite and devour a defenceless comrade.

Like the sea-stars, the crabs and lobsters enjoy the faculty not only of reproducing limbs accidentally lost, but also of voluntarily casting off not only their legs but even their heavy claws, when under the influence of terror. This curious process of self-amputation seems to be effected very easily, and without apparent pain, as they run off upon their remaining legs as if nothing had happened. The separation is soon followed by the formation of a cicatrice, from the surface of which sprouts out a small cylindrical appendage; this shortly after presents distinct articulations, and resembles, in miniature, the organ it is destined to form; but its growth is slow, and it does not for some time attain its full size, and thus specimens are frequently met with having one forceps much larger than the other.

It is evident how important this power of reproduction and self-amputation must be to animals whose fragile limbs are so liable to be snapped off by an enemy, and how greatly they must

be indebted to this invaluable privilege, which frequently enables them to save the whole by the temporary sacrifice of a part. Here also the wind is tempered to the shorn lamb!

The wonderful metamorphoses of the insects are universally known, but the changes which the young crabs, lobsters, prawns, and shrimps have to undergo, before they assume their definitive shape, are no less astonishing; for the forms of these larvæ are so peculiar, and so entirely different from any of those into which they are ultimately to be developed, that they were considered as belonging to a distinct genus, *Zoea*, until their real nature was first ascertained by Mr. T. V. Thompson. These infant crabs look very strange indeed. Fancy a preposterously large helmet-shaped head, ending behind in a long point, and furnished in front with two monstrous sessile eyes like the windows of a lantern. By means of a long articulated tail, the restless chimera continually turns head over heels. Claws are wanting, and while the old crabs crawl about on eight legs, the young have only four, armed at the extremity with four long bristles, that are continually pushing food towards the ciliated and ever-active mouth. Who could imagine that a creature like this should ever change into a crab, to which it has not the least resemblance? But time does wonders. After the first change of skin, the body assumes something like its permanent shape, the eyes become stalked, the claws are developed, and the legs resemble those of the crab; but the change is incomplete, for the tail is still long and furnished with false feet, like that of a lobster. The swimming-habit has not yet been laid aside. At the next stage, while the little creature is still about the eighth of an inch in diameter, the crab-form is completed, the abdomen folding in under the carapace. All the subsequent changes are merely changes of coat, consequent on the growth of the now complete animal.



Larva of Crab.

In these several metamorphoses we see portrayed in succession the peculiarities of three different types, one rising above the other in structure. In the first the crab is like one of the lowest and most incomplete crustaceans; further on it resembles

the lobster, and at last it appears in the compact shape which constitutes the highest perfection of crustacean life.

Providence has ordained that each class of animals should not only branch out into a multiplicity of forms, so as to be able to adapt itself to an immense diversity of local circumstances, but also that it should spread itself as far as possible over the surface of the globe.

Thus, though the crustaceans have their chief seat in the ocean and its littoral zone, yet several of their species ascend into the regions of eternal snow, while others hide themselves in the perpetual darkness of subterranean grottoes. The famous cave of Adelsberg in Carinthia is tenanted by several crustaceans, and the alpine-flea is found on the Aar-glacier, 8,500 feet above the level of the ocean.

Many crustaceans, averse to the briny sea, delight in the sweet waters of the river or the lake; others, finding not even sea-water salt enough to their taste, can only enjoy existence in saline springs; while others again entirely abandon the liquid element and live on the dry land, either sojourning, like our wood-lice, under stones and in cellars, or, like the land-crabs of the West Indies, in shady forests, where though they breathe, like their aquatic relations, through the medium of gills, the peculiar construction of their respiratory organs and the perpetual moisture of the climate render their existence possible.

While myriads of crabs people the slimy lagunes, or burrow in the sands skirting the ocean, or seek a shelter among the fronds of submarine forests, others love to sojourn in the deeper waters, or even to perform long sea-voyages, like the Nautilograpsus, which, though ill-formed for swimming, finds means to satisfy its roving propensities by clinging to the back of a turtle.

While the lower crustaceans abound in the Polar seas, crabs are completely wanting in those gelid waters: their number increases on advancing towards the equator, and attains its maximum in the torrid zone. Here we find the most remarkable and various forms; here they attain a size unknown in our seas; and here they do not, as with us, inhabit the salt waters only, but also people the brooks and rivers, or even constantly sojourn on land.

With the exception of the terrestrial Onisci, which chiefly

feed on decaying vegetable matter, of the Birgus or robber-crab, which delights in the sweet kernel of the cocoanut, of the water-fleas, which feast on the tender fronds of the green sea-weeds, and of a few other species, the crustaceans are eminently carnivorous. Their amazing numbers, their voracity, their powerful claws render them the most formidable enemies both of the weaker among their own class and of all the lower aquatic animals. Even the fishes and cetaceans are not exempt from their attacks; and as the whale, the carp, the sturgeon, the shark, the perch have each of them their peculiar crustacean parasites, it can easily be imagined how large the number of the still unknown species must be which feast on that vast host of fishes that has never yet been accurately examined. Some bore or eat holes into the skin of their victims, others fasten on their gills, and many settle in their entrails; where, no doubt, they lead a more pleasant life than that which, through their agency, falls to the share of their involuntary entertainers.

On the other hand, the crustaceans constitute a great part of the food as well of the sea-stars, sea-urchins, annelides, and many of the molluscs, as also of the fishes and sea-birds; and as they are found of all sizes, from microscopical smallness to a weight of several pounds, they are able to satisfy the wants of a great variety of animals.

Man also is indebted to the crustaceans for many a savoury morsel; and while the Europeans enjoy their lobsters, crayfish, and shrimps, the islanders of the torrid zone not only feed upon many marine crustaceans, but also upon the fat of the long-tailed Birgus and the white flesh of the land-crab. The injuries inflicted upon mankind by the crustaceans are certainly inferior to their services, though several species (*Chelura terebrans*, *Limnoria terebrans*) are great destroyers of submerged timber, and others are said to be poisonous.

A carnivorous race exposed to so many persecutions necessarily requires to be well furnished with the means of attack and defence. Thus in all the higher crustaceans we find, with rare exceptions, the anterior thoracic extremities terminating in pincers of greater or less strength, armed with teeth and sharp hooks which give them increased powers of prehension. Generally only the first pair of legs is converted into these formidable weapons, but in the crayfish the second and third pair of feet are likewise pro-

vided with smaller pincers, as a kind of reserve, in case the first pair should be rendered unserviceable; and in the Dromiæ we find the two posterior pairs of legs, which are of a much smaller size and raised above the plane of the others, similarly armed. These posterior claws, however, are not intended for active warfare, but merely for strategical purposes, as they serve to hold fast the pieces of sponge or other marine productions under whose cover the wily crustacean approaches and entraps his prey.


Sponge Crab. (Dromia vulgaris.)

A singular Tahitian crab observed by Mr. Bennett makes use of a similar artifice; but in this case the mask of decayed vegetable substances and coral sand, which enables the lurking ruffian to steal upon his victims unperceived, is not kept in its position by the hind-legs, but by the rigid and incurved bristles with which the back is covered. In these manœuvres he is very much assisted by the long ophthalmic peduncles, which, curving upward to raise the eyes above the pile of materials, give him the great advantage of seeing without being seen.

The sea-spiders do not indeed load themselves with a voluntary burden, which they are able to cast off again at pleasure, but their back is generally clothed with a mass of parasites, corallines, sponges, zoophytes, algæ or molluscs, so that the poor creatures have frequently to groan under a considerable weight. To this, however, they are no doubt in many cases indebted for their lives, as even a sharp-sighted enemy can hardly detect them under the mound of plants and small animals comfortably settled on their carapace. Besides the strong and heavy pincers with which the forefeet of the Birgus-latro are armed, this large tropical shore-crab has, like the Dromiæ, its last pair of legs terminated by narrow and weak claws, which, however, it puts to a very different use, for, living on the fruits of the cocoanut-tree, it requires no mask or artifice to surprise its prey. After having selected a nut fit for its dinner, the crab begins its operations by tearing the husk, fibre by fibre, from that end under which the three eyeholes are situated; it then hammers upon one of them with its heavy claws until an opening is made. Hereupon it turns round, and by the aid of its posterior pincers extracts the white albuminous substance.

In this wonderful instance of animal instinct, one knows not what is most to be admired—the beautiful adaptation of the animal's structure to its peculiar mode of life, or its almost incredible ingenuity.

The crustaceans have various modes of escaping the attacks of an over-powerful enemy. Some, like the shrimp or the lobster, bound rapidly through the waters; others, as we have seen, are excellent runners on the land. Many form deep burrows, into which they retire at the first alarm; others hide themselves quickly under boulders or tufts of algæ, to avoid a disagreeable meeting with a voracious fish or hungry kinsman. Some feign death, contracting their claws, and allowing themselves to be thrown about like inert bodies; others, like the small pea-crab, claim the hospitality of large bivalve shells, as a substitute for the softness of their own integuments. In this safe retreat they live upon the minute animals which their *involuntary* protector engulphs on opening his folding-doors; for it is of course but a poetical fiction that a friendly connection exists between them—that the mussel is warned of the approach of inquisitive cuttlefishes, or prying sea-stars, by a gentle pinch of his little lodger—and that the latter, when after an excursion he finds the premises closed, has only to knock to be again admitted!

Another large family of crabs is likewise indebted for a dwelling to another and a lower class of animals. The hermit-crabs or paguri have, indeed, the forepart of their body armed with stout claws and covered with a shield, but terminate in a long, soft, and utterly defenceless tail. This cumbersome and exposed hind-part is not formed for swimming, and its weight prevents them from running, so that nothing remains for the poor creatures but to look about them for some shelter; and this is afforded by several conchiform shells—buccina, neritæ—in which they take up their abode, attaching themselves to their interior by a sucker with which the tail is furnished at its extremity, and also holding by the six false legs which they bear at their hinder portion. When they are feeding or walking, the head and thorax project beyond the mouth of the shell; but when they are alarmed they draw themselves in, closing the mouth with one of the claws, which is much larger than the other, and fits the opening of

the shell as exactly as the lid or operculum of its original possessor. It is surprising how rapidly they will run about with the dwelling they have appropriated on their back; and when by the progress of their growth it becomes uncomfortably narrow, the remedy is easy, as convenient shells abound wherever hermit-crabs exist.

Thus we find a wonderful harmony between the organization of the paguri and the structure of the alien domicile to which they owe their safety, and which serves to complete their existence. Evidently the same creative idea has given birth to the mollusc and the crab, for how could mere fortuitous circumstances have produced so marvellous a relation between animals belonging to two classes so widely distinct?

In point of intelligence the crustaceans are far inferior to the insects. Their instincts are confined to the violent seizure or the cunning entrapping of their prey, to the burrowing of a hole in the ground, or to the seeking of a shell fit for the concealment of their otherwise defenceless body: in them we find no care for their young, no mutual affection, no joint labours for the welfare of a large community, no love—but frequent outbursts of an angry and quarrelsome temper.

The land-crabs, however, afford us a remarkable instance of that wonderful migratory instinct which in the following chapters we shall have frequent occasion to admire. These animals generally spend their days in holes and cavities among the mountains; but when the season for spawning arrives, vast armies of them set out from the hills, marching in a direct line towards the sea-shore, for the purpose of depositing their eggs, which are attached to the lower surface of the abdomen and are washed off by the surf. On this grand expedition they pursue so direct a line to the place of their destination that scarcely anything will divert their course; even the most formidable obstacles are overcome by their unyielding perseverance. When they have effected the purpose for which they undertook their journey, they recommence their toilsome march to their upland retreats. They set out after nightfall, and steadily advance until the approach of daylight warns them to seek concealment in the inequalities of the ground, or among any kind of rubbish, where they lie ensconced until the stars again invite them to pursue their undeviating course. Of the

thousands that originally left the damp forest-grounds, comparatively but a small number return, emaciated and exhausted, to their mountain-burrows, and a few weeks after, millions of the little crabs which have been hatched on the shore may be seen making their way up to the hills. Who can explain to us the mysterious voice which prompts them to seek an unknown home, so different from the scene where they first drew breath; who tells them that far from the torrid shore they are sure to find a more congenial retreat in the cool shades of the forest; and who, throughout countless years, directs these constant migrations from the sea to the uplands, and then again from the mountains to the brink of the ocean?

CHAPTER XXII.

INSECTS.

Their Integuments—Their Metamorphoses—Larvæ—Pupæ—Perfect Insects—Antennæ—Eyes—Masticatory Organs—Chewing and Sucking Insects—Digestive Organs of the Carnivorous and Herbivorous Insects—Motions of Insects—Elateridæ—Aquatic Insects—Foot of the Fly—Wings—Respiratory Organs—Tracheæ and Stigmata—The Butterfly's Wing under the Microscope—Defences of Insects—Vitality—Concealments—The Caddice Fly—The Small Ermine Moth—The Clothes Moth—Hunting Manœuvres of the Mantis—The Ant Lion—The Larva of the Tiger Beetle—Insect Plagues—Insects Useful to Man—Their Numberless Enemies—Their Wonderful Instincts—Care for their Young—The Rhynchites Betulæ — Dung and Sexton Beetles—Their Remarkable Intelligence—The Sand Wasp—Ichneumon Flies—Breeze Flies—The Earwig—The Mole Cricket—The Dirt Dauber and Trypoxylon—The Leaf Cutters—The Carpenter Bee—The Chartergus Nidulans—The Hive Bee—The Ants and Termites.

Though small in size, the Insects are great, by their infinite varieties of form, their prodigious numbers, their wonderful organization, their astonishing metamorphoses, and their truly marvellous instincts. From whatever point of view we may consider them, they constantly afford new subjects of admiration and delight; for all that is either beautiful and graceful, interesting and alluring, or curious and singular in every other class and order of the animal world has been combined and concentrated in these miniature masterpieces of Nature, a glimpse into whose economy opens to every reflective mind the portals of the spiritual world, and plainly reveals the Deity who called them into life.

A thick and weighty harness of chalk, like that of the crustaceans, would have been far too cumbersome for delicate and tiny creatures, generally destined for rapid motions; and thus we find the insects covered with a thin vestment of incorruptible *chitine*, a hornlike substance equally light and strong, which, without considerably adding to their weight, answers every

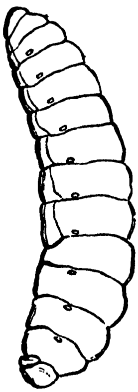
purpose of protection, and, shaped into myriads of graceful forms, frequently glows with the most vivid colours. A robe more beautiful and appropriate than this cannot possibly be imagined.

A closer examination of the insect-skeleton shows us that it consists of a number of rings or segments, either distinct or soldered together, and forming three principal parts—the head, the breast or thorax, and the abdomen. The head, which has generally the form of a hollow globe, is the product of at least three segments moulded into one, and contains the organs of mastication, the antennæ, and the eyes; the thorax invariably consists of three rings or segments, and bears the single or double pair of wings which *most* of the perfect insects possess, as well as the three pair of feet with which *all of them* are furnished; the abdomen, finally, is formed of a larger number of distinct segments, freely moveable one above the other.

Such is the ground-plan according to which the skeleton of all insects is constructed, but their forms are varied to answer an infinite variety of wants: for the insects gnaw and devour all organic substances without exception; they feed upon the whole vegetable kingdom, from the palm to the lichen, and from the hardest root to the most delicate blossom. They are not only at perpetual feud among themselves, but engaged in constant war with the higher animals; they inhabit every climate; they select every conceivable dwelling-place, from the caverns of the subterranean world to the pinnacles of the Alps; and thus we can conceive the endless varieties of structure, of instruments, and weapons which the immense range of their existence naturally requires.

More than one hundred thousand different species of insects have already been described by entomologists, and each of them is distinguished from its nearest relations by some modification of structure best adapted to its peculiar sphere of life. The most retentive memory would be utterly unable to embrace this amazing variety of forms; and yet a vast number of insects is still utterly unknown, and their countless legions constitute but a part of the animated beings that people our little earth—itself but a speck in the boundless universe! How wondrous are the works of the Creator—how beyond all human conception His wisdom and His power!

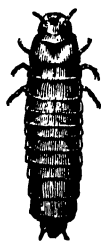
The immense gallery of insect life swells into still grander proportions when we reflect that each insect passes through several metamorphoses or stages of development before it assumes its perfect form, exhibiting as it were several distinct beings during the course of its existence. At first it issues from the egg either as a head-and-footless maggot (*a*), or provided with a head and six thoracic legs like a true larva (*b*), or possessing a still larger number of feet like a caterpillar (*c*). A boundless appetite, an insatiable voracity characterise this first juvenile age of insect life. Thus, to mention but one instance, the silkworm, which at its birth weighs but the hundredth part of a grain, devours in thirty days more than an ounce of leaves, sixty thousand times more than its original weight! According to this mea-



a

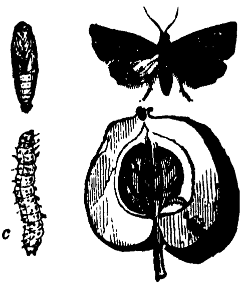
Maggot of Hornet.

b



Larva of Calosoma sycophanta.

c

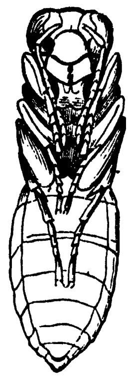


Apple Moth, with the Caterpillar and Chrysalis.

sure a child, which when born weighs about ten pounds, would consume during the same period no less than 6,000 hundredweight of food, to the amazement and terror of its parents. No wonder that so vast a supply of aliment produces a rapid growth, and that during the thirty days of her existence the silkworm larva increases 9,500 times in weight; no wonder also that she soon feels her dress too narrow, and more than once sheds her skin to provide room for the swelling proportions of her body! But now a period of inactivity succeeds, and, generally after the fifth shedding of her skin, a great change takes place in the

habits of the gormandizing larva. A total want of appetite succeds her voracious hunger, she seems to loathe the succulent leaf on which she had feasted, and seeks a quiet retreat to undergo her next transformation.

In the pupa state she now does penance for her previous excesses, and, like an Indian fakir, remains in a motionless condition. Frequently the skin she last has shed, forms a dry and shrivelled covering in which she remains encased, or she spins for herself a silken dwelling in which she awaits her transformation, or prepares a little cavity in the earth and lines it with silk for the same purpose, or suspends herself from the undersurface of a leaf. But during this period of apparent rest, this total seclusion from the outer world, the greatest activity prevails within; all the organs needed by the perfect insect are developed, and when their formation is completed, she bursts her bonds, and, armed with wings, emerges to the light of day as a lustrous beetle or as a gay butterfly—the symbol of immortality.


Nymph or Pupa state of Hornet (magnified).

But the changes of form in passing from one state to another are not in all instances so complete: frequently the larva bears a more or less close resemblance to the perfect insect; and many pupæ continue to feed, or to move about, or exhibit rudiments of wings, when winged in the perfect state. This incomplete metamorphosis, confined to repeated sheddings of the skin, takes place for instance with the dragon-fly, the grasshopper, and the cockroach; while a complete transformation characterises the beetles, the butterflies, the flies, ants, wasps, and bees.


The Hornet. (Vespa crabro.)

The perfect insect ceases to grow; its appetite is moderate, or even totally fails. Its chief care is the preservation of its

species, and after having laid its eggs it generally lies down and dies.

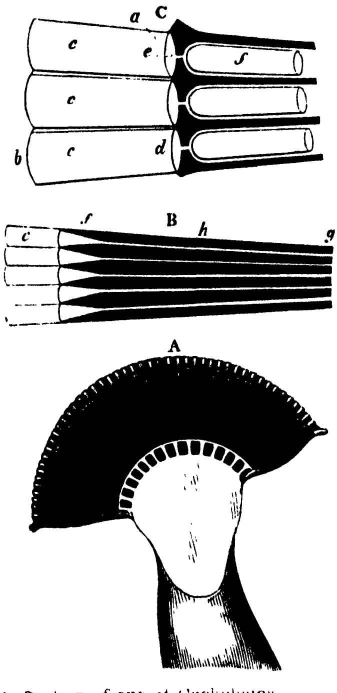
The jointed antennæ of the innumerable insect tribes exhibit a wonderful diversity of form; now drawn out into a thread, and now ending in a knob—now pectinated like a comb, and now expanding like a fan. We find them smooth or hairy, simple or divided into branches, projecting or recurved—sometimes short, sometimes of a length far surpassing that of the body. When the insect is in motion, they are stretched out and expanded to their fullest extent; but by many species they are immediately retracted on the occurrence of any loud or sudden noise —and then there is in many cases a channel or groove ready to receive, to hide, and to protect them against many injuries.

That organs so beautifully constructed and so carefully provided for, must necessarily be of the highest importance, is evident; but strange to say, their use has not yet been fully ascertained. The late Professor Erichson of Berlin discovered their solid case to be perforated by a number of little holes lined internally with a delicate membrane; and as the air can thus easily penetrate into their cavity, this distinguished entomologist considered their function to be that of smelling. Others, again, are of opinion that they are auditory organs, and in many cases there can be no doubt that their office is that of touching or feeling other objects. Thus the honey-bee when constructing its cells ascertains their proper direction and size by means of the extremities of its antennæ, while the same insect, when evidently affected by sounds, keeps them motionless in one direction as if in the act of listening.

Wherever the sense of smelling in insects may reside, there can be no doubt of its exquisite acuteness, particularly in those species that live on decayed or putrid animal substances, and occupy a high rank among the scavengers of Nature. Scarcely does a substance answering their wants drop to the ground, than the dung-beetles are seen hurrying along from distances proportionally as remarkable as the vast spaces measured by the vulture's eye. A loud and joyous hum accompanies their active flight, which in strength and duration surpasses that of all other beetles, and materially assists them in the performance of their useful labours.

Sir Emerson Tennent was once present at the death of an elephant, and saw how the flies, of which not one was visible

but a moment before, arrived in clouds and blackened the body by their multitude: scarcely an instant was allowed to elapse for the commencement of decomposition, no odour of putrefaction could be discerned; yet some peculiar smell of mortality, instantly spreading to a distance, must have struck the sharp scent of the insects and summoned them to the feast.



A. Section of eye of Cockchafer.
B. Section of eye of Dragonfly.
C. Section of the same still more magnified.

c facets, *b* external convex surfaces, *d* base, *a* anterior chamber between facet and iris, *e* pupillary aperture, *f* cones filled with vitreous humour.

The sense of smelling is no less acute in the ants. When in a tropical climate—where, as is well known, these active little creatures chiefly abound—a small piece of sugar covered with paper is placed in the centre of a table, not many minutes will elapse before a troop of ants is seen to approach, and to form a long line in order to convey the booty in safety to the floor of the room. The sense of smelling can have been their only guide to a substance which to our grosser olfactory nerves seems but faintly scented even at a short distance. While nothing positive is known about the organs which are the seat of this remarkable faculty, the eyes of insects strike us at once by their large size and brilliancy. They do not turn in their sockets like ours, but this want of motion is pensated for by their amazing number; for the microscope teaches us that they are not simple like ours, but composed of a multitude of distinct organs of vision, divided from each other by interstices covered with a dark pigment, and converging to the centre of the eye, each possessing its separate cornea, and each provided with a separate filament of the optic nerve. Externally they form a network of transparent facets, generally of an hexagonal shape, which by the refraction of the light produce

the peculiar satin-like lustre of the insect's eye. Their number is almost incredible, for in the domestic fly there have been reckoned 4,900, in the cockchafer 6,300, and in some butterflies no less than 60,000 eyes, each receiving its separate ray of light and transmitting the impression to the brain!

The use of this compound structure of the organs of vision is evident, for had the eye of the insect been simple as ours, it would have required a large number of muscles, occupying a considerable space and adding greatly to the weight of the head, to turn it in its socket, and a constant attention and change of position to protect its owner from the manifold dangers to which he is exposed; while now, with its thousands of eyes collected into two prominent and immoveable groups, and economizing both space and labour, the insect without any effort constantly commands a vast horizon.

Who would not have imagined that instruments so prodigally endowed would have sufficed for every purpose? but in many cases two or three minute and simple eyes, situated on the forehead or summit of the head, have been superadded to their number.

The celebrated physiologist Professor Müller is of opinion that the function of these simple eyes is confined exclusively to the perception of near objects, and that of the compound eyes to more distant ones; so that we thus find the sight of many insects as capable of embracing every range of vision, as civilized man with the artificial assistance of his near and farsighted spectacles.

The simple eyes or ocelli constitute the only organs of vision in the larva state, where the compound eye would clearly have been superfluous; as at this early stage of their development insects are not obliged to seek their food at any great distance, and, were they able to perceive an enemy from afar, have not the power of escaping by a rapid flight.

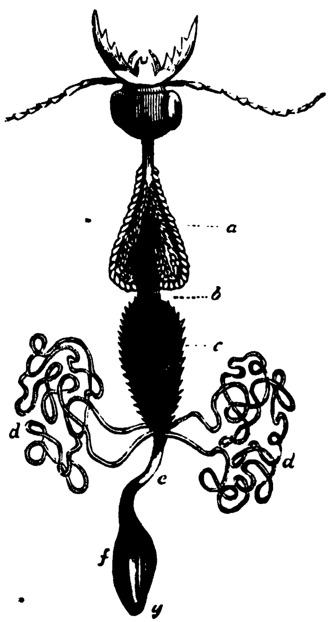
As the food of the different orders of insects is extremely various, it may easily be imagined that their mouths must also be very differently constructed. In those which bite, tear, or lacerate, it is furnished with very strong jaws, often notched or serrated on the inner side into the appearance of teeth, and sometimes decussating like the blades of a pair of scissors; in others it consists of a tube or instrument for suction, either simple or armed with various kinds of appendages.

Thus in the Tabanidæ it is furnished with sharp lancets, to

enable these parasitic blood-suckers to pierce the skin of other animals; while in the common house-flies, whose food is entirely fluid and easily accessible, all the parts of the mouth are soft and fleshy. In the bee the part employed in gathering or sucking honey is not tubular but solid, and consists of a long tapering tongue formed of an immense number of short annular divisions, and densely covered throughout its entire length with long erectile hairs. Closely packed up and concealed when at rest, it reaches to a great distance when actively employed, and laps up the sweet juices concealed at the bottom of the flowers by a constant succession of short and quick extensions and contractions.

In the moths and butterflies the sucking-tube, tongue, or proboscis is rolled up like a watch-spring when at rest, but capable of being darted forth in an instant, and sucking up with great rapidity the nectareous fluids on which its gay volatile possessor lives.

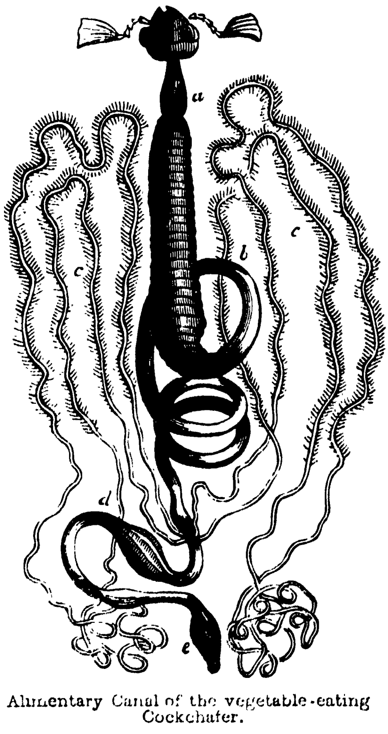
The carnivorous dragonfly is armed with a kind of flat proboscis, with a joint in the middle and a pair of strong hooks or prongs at the end. This proboscis, when the dragonfly is at rest, is folded or turned up in such a manner as to lap over the face like a mask; but when the creature sees any insect which it means to attack, it springs suddenly forward, and by stretching forth the jointed proboscis readily obtains its prey.



Alimentary Canal of the carnivorous Green Tiger-beetle.

The digestive apparatus of the carnivorous insects differs considerably from that of the vegetable-feeders. In the former the intestine passes nearly straight through the body with few enlargements in its course, and the glandular organs have a simpler structure.

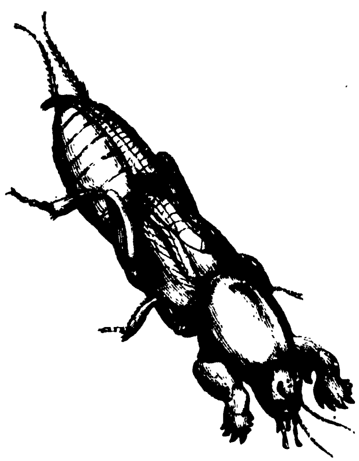
The wide and glandular crop (a) passes the food into a comparatively small stomach (b c), and the liver (d) consists of a few simple biliary ducts. All this corresponds with their easily digestible food, while in the vegetable-eating insect the alimentary canal is more lengthened, convoluted, and capacious, with numerous dilatations, and the glandular organs are more developed in order to subdue the resistance of more refractory aliments. Thus in the cockchafer the stomach (b) is extremely long; the intestine has several enlargements or supplementary stomachs, as they might be called, for extracting every nutritious particle from the tough leaves on which this destructive beetle subsists; and the liver (c c), which is here of great magnitude, has its secreting surface much extended by the development of innumerable minute cæca from its primary ducts.



Alimentary Canal of the vegetable-eating Cockchafer.

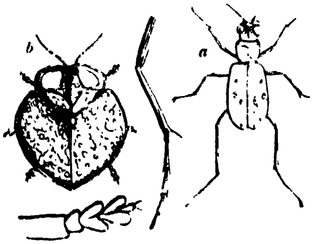
In the class of insects we find all the various modes of motion united that are but partially scattered among other animals. They walk, they run, they jump, they climb, dig, and burrow with the quadrupeds; they rival the birds in rapidity of flight, they glide along with the agility of serpents, and the fishes are not more perfect swimmers; so that it may be said without exaggeration that these restless little creatures, formed alike for the earth, the waters, and the air, give life to every portion of our globe. The construction of their feet corresponds in an admirable manner with their various modes of motion, so that a mere glance at an insect's legs suffice to give us an idea of its way of life. Thus the excessively strong forelegs of the mole-cricket, with their broad

feet divided into sharp and claw-shaped segments, evidently belong to an animal made for burrowing in the earth; while



the enormous hind-legs of the grasshopper point at once, by their great length and the robustness and thickness of their thighs, to the vast leaps which their predaceous owner is capable of executing. A flea is known to clear at a single jump a space equal to two hundred times its own length; but this almost incredible feat is at once explained by the great size and strength of its muscular legs, the joints of which are, moreover, so adapted that it can fold them up one within another, and in leaping they all spring out with prodigious force.

How small and tiny are the feet of the indolent tortoise-beetles, who, clinging to leaves, require no great agility of



a Tiger-beetle.
Tortoise-beetle.

motion; how long and well-developed those of the nimble Cicindelidæ, whose life is spent in the constant pursuit of prey! The racehorse and swiftest greyhound would be distanced by many an insect runner, were the size of the little creature but equal to the strength and agility

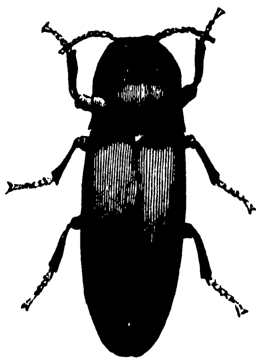
Several insects execute prodigious feats in jumping by means of other organs than their legs. Thus the maggot of a little black fly (*Tephritis putris*), common in our richest cheeses, accomplishes its enormous leaps somewhat in the same manner salmon, by taking the tail in the mouth and then suddenly

letting it go again. Swammerdam relates that he beheld one, which was not more than the fourth part of an inch in length, jump out of a box six inches in depth; which is as if a man six feet high should raise himself in the air by jumping 144 feet, a piece of agility evidently far surpassing the powers of Leotard himself!

The Podurinæ, or springtails, make use with a similar effect of the long-forked process with which their body is terminated: while at rest, it is bent forwards beneath the abdomen, but on being suddenly extended backwards it jerks its owner high into the air.

Springtail.

The Elateridæ leap in a still more extraordinary manner. Their legs are so short that they are unable to right themselves again when placed on their back; but Providence, which leaves none of its creatures unprotected, has given them another means to extricate themselves from this unpleasant situation. A strong spine situated beneath the thorax fits at pleasure into a small cavity on the upper part of the abdomen, and having been withdrawn from its socket, springs back with considerable force; thus jerking the body several inches high into the air, and enabling it to regain its natural position. If the elater does not alight upon his feet in the first instance, he repeats his leap until he has gained his point.

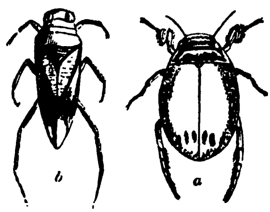


Elater noctilucus (Click-beetle).

Legs such as those of the grasshopper or mole-cricket would have been but of little use to insects dwelling in the water; but as we find the feet of the seals and walruses, which likewise spend the greater part of their existence in water, converted into fins which enable them to emulate the fishes in swimming, thus also the feet of the aquatic insects are admirably adapted to their peculiar mode of life.

The four posterior legs of the Dytiscidæ or water-beetles are not only broad and flattened like oars, but ciliated along their internal margin, by which means the rowing surface is still more

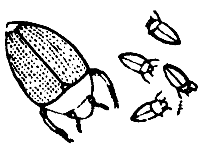
increased. A great development of thigh gives the movements the necessary force, and the broad, flat, sharply-margined body is well adapted for cleaving the waters with facility. Thus equipped, these voracious insects, resting motionless on the surface of the water with their heads downwards, in order to watch for their prey beneath, dart down upon it with surprising swiftness, and make great havoc not only among other water-insects, but even among the smaller fishes. Their larvæ, distinguished by a long shrimplike body, and using their tail as their chief instrument of locomotion, are no less active and voracious than the full-grown insects, so that in both forms the Dytisci are among the most mischievous animals that can infest a fishpond.



a Water-beetle.
b Boat-fly.

The Notonectidæ, or boat-flies, are no less beautifully formed for rapid progression in the water. They generally swim on their backs, which are shaped like the bottom of a boat; and the hind-legs, which are thrice as long as the forelegs, have like those of the Dytisci a fringe of bristles along their edge, by which the surface with which they strike the water in swimming is greatly increased. Their eyes are so placed that they are able to see both above and below the surface of the water, so that at the approach of danger they instantly descend and vanish from the sight. Woe to the unfortunate snail or aquatic Oniscus they descry in their excursions, for with the rapidity of lightning they dart upon their victim from a distance of several inches, and kill it almost instantaneously with a venomous sting!

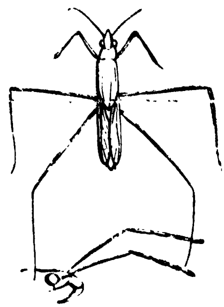
Curveting about in every direction, the small whirligigs or Gyrini animate, during a fine summer's day, the surface of quiet waters. The rapidity with which they skim in undulatory circles is not less admirable than the precision with which they thread the mazes of their aquatic dance, so as never to encounter and seldom to touch each other. Their flattened and oar-shaped hind-feet are peculiarly adapted for these graceful



Whirligig.

evolutions, which they frequently continue for hours together with unwearied zest, while their far longer forefeet are no less admirably formed for seizing their prey.

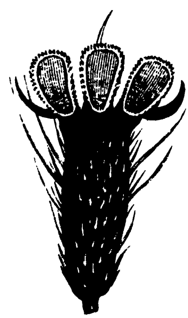
Like them, the Hydrometridæ may be met with in every pond or stream, skimming along the surface, and turning with the greatest rapidity. The body is boat-shaped, the hind-feet serving as a rudder; while the two middle feet brush along the surface of the water, and give the required motion. The under side of the body is clothed with a thick coating of fine hairs, evidently intended to prevent the insect from coming in contact with the water.



Hydrometra stagnorum.

By means of the strong hooks or claws with which their feet are usually armed, most insects are able to climb with great facility on a rough surface; while others are provided with a more complicated apparatus, which enables them to ascend vertically on

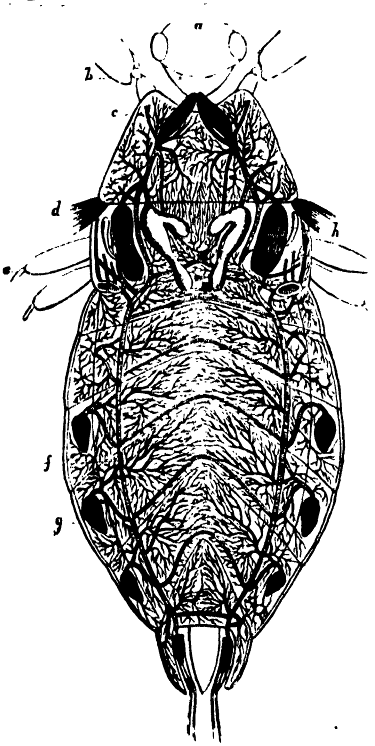
Foot of Domestic Fly.



Foot of Bibio febrilis.

the surface of glass, or to remain suspended in an inverted position from the ceiling. We have a familiar example in the house-fly, which has the extremities of its feet furnished with two funnel-shaped membranous suckers, moveable by muscles in every direction, by which they are capable of exhausting the air on very smooth surfaces—thus causing the pressure of the atmosphere to sustain the weight of the body. The area of these suckers is so beautifully adjusted to the

weight of the insect, that the pressure of the air alone is more than sufficient to sustain it without exertion, and, as it were, to set the force of gravity at defiance. In the Bibio febrilis the foot is furnished with three suckers, and in the Cymbex lutea with five. Many other species, amongst which is the common wasp, are similarly furnished with cushions and analogous suckers, which enable them to ascend vertically on glass.

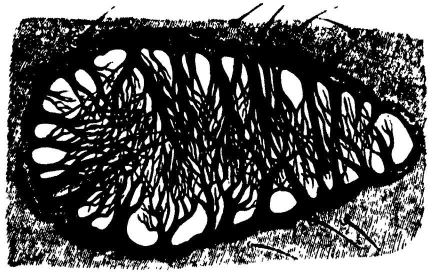


Tracheal System of Water Scorpion.
a head, *b* first pair of legs, *c* first segment of the thorax, *d* second pair of wings, *e* second pair of legs, *f* tracheal trunk, *g* one of the stigmata, *h* air-sac.

Most of the perfect insects have their body most admirably organised for flight. In all its parts it is traversed by numerous air-tubes, communicating with several external openings or spiracles, and not only branching out into numberless ramifications, so as to penetrate even the smallest and most delicate organs, but frequently also dilating into vesicles or sacklike expansions, the size and number of which is always in exact proportion to the powers of flight; their development being most considerable in the bees, flies, and butterflies, while there is not the slightest trace of them in the wingless larvæ, or in insects that constantly reside on the ground.

Thus by a most beautiful mechanism the tracheæ or air-vessels not only abundantly supply the insect with all the oxygen needed for its active habits of life— they not only act as lungs or respiratory organs, but diminish at the same time the specific gravity of its body, and enable it to support itself on the wing with less muscular effort. The spiracles, stigmata, or

breathing-pores through which the air enters and is discharged, and which are generally visible on the exterior of the body of the insect as a series of pores along each margin of the under-surface, are also most admirable instances of Provident Wisdom. For to prevent the entrance of minute particles of dust or soot—which, were their orifices widely open, would be continually entering and disturbing the functions of respiration—they are generally furnished with a sieve, consisting either of an interlacement of minute branches, as in the common fly, or of a membrane perforated with minute holes, as in the larva of the cockchafer; and thus in every detail of insect economy we find models of perfection worthy of an Almighty Hand.



Spiracle of Common Fly.

The articulated abdomen, extremely moveable in those insects which sustain the longest and most powerful flight, serves as a rudder, like the tail in birds; and the wings are invariably situated as near as possible to the centre of gravity, so that the weight they have to carry may be equally balanced, and their task rendered more easy. These organs, so fragile and seemingly so weak, are frequently endowed with wonderful powers, so that in point of celerity many insects, comparatively to their size, fly much quicker than any birds. It has been calculated that the common fly in its ordinary flight makes with its wings about 600 strokes, which convey it five feet every second; but if alarmed, their velocity can be increased six or sevenfold, or to thirty or thirty-five feet in the same period—a speed which emulates even that of the greyhound or the hare. The strength of muscle and nerve requisite for such a rapid action is truly amazing, and beautiful indeed must be the structure capable of exertions such as these!

As in the birds, the powers of flight are very unequally distributed among the insects, but always in strict accordance with their wants. Wings would have been perfectly useless to the numerous parasitic tribes, whose sphere of existence is confined to the narrowest limits; and the countless hosts of creeping or

running larvæ, from which, after incalculable losses, the winged legions of the beetles and flies emerge, are likewise doomed to a wingless state. Where food is always near at hand in inexhaustible quantities, or where, as in the grasshoppers, the leaping faculty is extremely developed, the powers of flight are proportionally less active, while they appear to perfection in such vegetable-feeders as are obliged to roam about constantly from flower to flower, or in those predaceous insects that feed upon a volatile prey scarcely less active than themselves. Thus we see the dragonfly darting with the velocity of a hawk over rivulets and ponds, over meadows and hedges, and rivalling the sparrow in the extermination of gnats and flies. While it performs its evolutions, the delicate transparent tissue of its large gossamer pinions gleams in the broad sunshine with all the colours of the rainbow; but still richer tints, a still more gorgeous metallic brilliancy adorns the wings of many beetles and butterflies.

We admire the mosaic works of the Italian artists, where thousands of minute stones are joined together with such consummate skill as to deceive the eye, and rival the finest pictures in harmony of outline and colours; but yet how coarse are these masterpieces of human skill when compared with the texture of the butterfly's wing, where countless scales, undistinguishable by the naked eye, form patterns of the most exquisite beauty!

On examining a plate of mosaic through a microscope of very moderate strength, it looks no better than the roughest patchwork of a savage, while the unparalleled perfection of the butterfly's wing first comes to light under a strong magnifying power. Then it is seen covered with regular rows of scales, each row overlapping a portion of the next, so that the surface appears tiled like the roof of a house; and each scale shows itself regularly marked by narrow longitudinal ribbings, and furnished with a sort of handle at one end, by which it is fitted into a minute socket attached to the surface of the insect. Each scale consists of two superficial coloured laminæ, inclosing a central lamina of structureless membrane, the surface of which is highly polished, and which acts as a foil to increase their brilliancy by reflecting back the light that passes through them.

Thus each scale is in itself a masterpiece of art, and many

thousands of these minute gems are required to deck the wings of a single butterfly. No monarch is more richly robed than this mean little insect, which each summer brings forth in millions!

Pursued by a thousand enemies, encompassed by a thousand dangers, the insects must long since have perished, had not the Beneficent Creator provided them with defences sufficient to counterbalance the perils which continually menace their existence. Many, without being obliged to use the least exertion, are protected by their colour or their form against numberless attacks. The grey darkly-spotted Curculio nebulosus is so like the soil upon which he is generally found, that he will deceive even the searching eye of the entomologist; and the Cassida viridis or common green tortoise-beetle, often seen during the summer months in gardens on the leaves of mint, is so like in colour to the herbs on which it lives, that, still further protected by its usual immobility and flattened form, it can hardly be distinguished from an excrescence of the plant.

The wings of almost all the moths are mottled, and variegated with dull colours, so that these hesperian or nocturnal insects need not shelter themselves under cover, but securely repose during the day in the crevices of the bark of trees, or on old walls and palings; and being perfectly motionless, their colours harmonise so exactly with these objects that they are overlooked by their enemies. To cite but one example, the wings of the English lappet-moth so exactly resemble, both in shape and colour, an arid brown leaf, as to deceive the most inquisitive eyes.


Lappet-moth.

Even the brightest of our butterflies are similarly protected. The beautiful Vanessæ, the upper surface of whose wings is so richly illumined, are on the underside all black or brown, or striped with grey, so that it is difficult to distinguish them from the ground or the trunks of trees, on which they repose with folded wings.

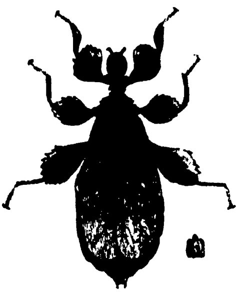
Several of the beetles belonging to the families of the Trogidæ and Curculionidæ, by the spinelike protuberances and deep sulcations of their wing-cases, resemble the dried hispid seeds

of plants. But the delusion of form and colour is nowhere carried to such perfection as in the family of the Phasmidæ,

Peacock Butterfly.
(Vanessa Io.)

Red Admiral Butterfly.
(Vanessa atalanta.)

popularly known under the name of 'walking-sticks' and 'walking leaves.' The latter, exhibiting the most cunning of all Nature's devices for the preservation of her creatures, are found in the Indian jungles in all varieties of hues, from the pale-yellow of an opening bud to the rich green of the full-blown leaf, and the withered tint of decay. So perfect is the imitation of a leaf in structure and articulation, that these amazing insects, when at rest, are almost undistinguishable from the foliage around; not only are the wings modelled to resemble ribbed and fibrous follicles, but every joint of the legs is expanded into a broad plait, like a half-opened leaflet. They rest on their abdomen, the legs serving to drag them slowly along, and thus the flatness of their attitude adds still further to the appearance of a leaf. This wonderful plantlike semblance extends even to the eggs, which might at first sight be mistaken for the deeply-ribbed seeds of various umbelliferous plants.



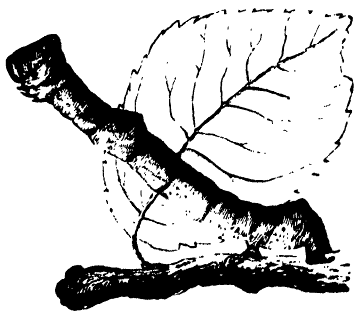
Walking Leaf-insect and
Egg (Phyllium siccifolium.)

Many insects are defended by the extreme hardness of their external coverings, which, though not capable of resisting the powerful beak of a raptorial bird, still shield them against the attacks of many an enemy of their own class. The flinty hardness of a beetle's coat-of-mail will frequently set the pin of the entomologist at defiance, and even the skin of the common horse-fly is so tough that the utmost pressure of the finger and thumb will hardly deprive the little creature of its life.

Others are endowed with so wonderful a vitality that they resist for a length of time, or survive almost incredible injuries.

Thus grasshoppers will sometimes outlive immersion in boiling-water, or bear, without expiring, the removal of their intestines; a mite has been known to live eleven weeks, without food, gummed to the point of a pin; and Swammerdam affirms that the chameleon-fly will retain its vital powers for forty-eight hours after being immersed in spirits of wine. The wonderful vitality of insects is shown also in the comparatively little pain they appear to feel from injuries, which to us would occasion excruciating torment, or instant death. This insensibility is manifestly a wise and merciful provision of the Almighty towards those of His creatures which, of all others, are most liable to accidents from the number and variety of their enemies.

Many insects seek to escape from danger by feigning death. The larva of Hydrophilus piceus becomes suddenly flaccid and soft on being touched, as if it had long ceased to live: and the common dungchafer, when touched, or in fear, sets out its legs as stiff as if they were made of iron-wire, and remains perfectly motionless. At the approach of danger the Buprestidæ and many of the weevil-beetles drop down from the leaf on which they feasted, and then even the keenest eye is frequently unable to distinguish them from the ground on which they fell. The caterpillars of the looper-moths when at rest support themselves for hours by means of their hinder-feet only, raising the body high in the air, and preserving it in a stiff straight line, or in a curve. The colour of the skin exactly resembles that of the stem or bark of the tree upon which the caterpillar feeds, and so complete is the deception that a person, after having had one of these deceiving masqueraders pointed out to him, can hardly be persuaded that it is anything else than a twig. Thanks to its attitude, it deceives the numerous small warblers which are constantly searching for insects among foliage; while other caterpillars, such as those of the hawk-moths, endeavour to repel the attacks of their enemies by



Caterpillar of looper-moth.

assuming attitudes of a threatening or terrific character. A considerable number of insects defend themselves by the secretion of poisonous or fœtid scents or fluids. Thus many of the tropical ants emit a corrosive acid, which, infused into the wound caused by their mandibles, produces the most excruciating pain. Woe to the naturalist who, ignorant of the fact, endeavours to break off a shoot of the Triplaris, or merely knocks against this tree, whose hollow branches harbour one of the most ferocious ants, for thousands will instantly issue from small round lateral openings in the plant, and fall upon him with fury! The touch of a red-hot iron is not more painful than their bite, and the inflammation and pain last for several days after.

Caterpillar of Hawk-moth.

But the most extraordinary insects possessing this species of defence are the beetles called *bombardiers*. The most common species (*Brachinus crepitans*), when pursued by some formidable enemy, seem at first to have no mode of escape, when suddenly a loud explosion is heard; and a blue smoke, attended by a very disagreeable scent, is seen to proceed from its anus, and this immediately stops the progress of its assailant. When the latter has recovered from the effects of this discharge, and the pursuit is renewed, a second in like manner arrests its course. The little artilleryman can fire his gun twenty times in succession, if necessary, and so gain time to effect his escape. The smoke has a strong and pungent odour, very similar to that of nitric acid; it is caustic, and produces on the skin the sensation of burning. Other insects, to whom such energetic means of defence have been denied, have recourse to concealment for their safety. Thus the small aquatic beetles creep under the mud, to be secure, while feeding, from the larger predaceous sorts which surround them. The Reduvius personatus, a species of bug, hides itself under a thick coat of dust, which answers the double purpose of stratagem and protection; and some of the tortoise-beetles have the still more singular custom of sheltering themselves under a canopy affixed to their tail, and formed of their own excrement; this they elevate in the air, bringing it over

their body, precisely the same as we should hold an umbrella.

Though caterpillars are frequently protected against injury by tufts of hairs, by acrid secretions, by stinging properties, or by closely resembling in colour the leaves upon which they feed, yet concealment is their most ordinary mode of defence. Sometimes the whole brood spins a common web, like a large tent,

Caddice

under which all the community for a part of their lives reside; sometimes every individual rolls himself up in a leaf, like a solitary hermit, so as to be completely hidden, and inaccessible to his enemies.

The caterpillars of the caddice-flies, so common in streams and ponds of water, enclose themselves in moveable tubes, and crawl about, like their representatives the hermit-crabs, at the bottom

of the liquid element. During the inactive chrysalis state, it is necessary that the open end of these cylindrical cases should be sufficiently closed to prevent the intrusion of enemies, and still admit the water necessary for their existence; but a most admirable instinct has taught the sagacious little creatures to provide for this want by the interweaving of a grate, or portcullis, at each end of their fortress, which at the same time keeps out intruders, and admits the water. Several dendritic caterpillars arm their cases in a no less curious manner with thorns taken from the tree itself on which they dwell, thus causing the nest to harmonize so perfectly with surrounding objects that it is not very easily perceived. The thorns are all disposed with

Small Ermine Moths

their points outwards, and are stuck into a strong glutinous material of which the body of the case is composed, like the spikes of a *chevaux-de-frise*. As long as the caterpillar remains in its larval state, and is obliged to feed, it traverses the branches freely, carrying with it the prickly home, and bearing the whole of its weight as it moves. But when the pupal stage has nearly arrived, the nest is suspended to the branch by strong silken threads, and thenceforth remains immoveable.

Among the social caterpillars those of the Small Ermine deserve particular notice. They live in large tents, placed

among the branches of some tree, and composed of silken threads, which are loosely crossed and recrossed in various directions. From this citadel the caterpillars issue in vast numbers, each individual spinning a strong silken thread as it proceeds, which acts as a guide to the nest, just as the thread of Ariadne led Theseus through the mazes of the Cretan labyrinth. When once these caterpillars have taken possession of a tree, they are sure to strip it of its leaves as completely as if the breath of winter had laid them low.

It is a very curious sight to watch the systematic manner in which these troublesome insects set about their work; how they send out pioneers, which lead the way to new branches, either by crawling up to them, or by lowering themselves to them by means of their silken cordage; and how the vanguard is soon followed by a troop of ever-hungry companions.

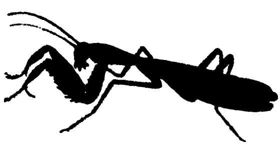
Though very conspicuous, especially when making their way from bough to bough along their silken bridges, they are secure from the attacks of sparrows or other small birds; for their threads, traversing the branches in all directions, act as an effectual barrier, by striking against the wings and terrifying their aggressors. These threads are very elastic, and of marvellous strength, considering their tenuity, producing most uncomfortable sensations when they come across the face. Thus these destructive caterpillars are able to rob the orchards with comparative impunity, and the only way to prevent their damages is to destroy their nests in early spring, before they have had time to sally forth.

The industry of the clothes-moth in weaving its little den of refuge is no less remarkable. Having spun a thin coating of silk round its body, it cuts filaments of wool or fur close to the thread of the cloth, and applies the pieces to the outside of its case, which covering it never leaves except in cases of urgent necessity. When it wishes to feed it puts out its head at either end of the case, as best suits its convenience. When inclined to change its position, it protrudes its head and about half its body, dragging its case by fixing its hind-legs firmly in it; and when, from its increase in size, the case becomes too small, it makes an addition to it at each end. This operation can be readily traced by transferring it from cloth of one colour to another, when each addition will be conspicuous from the difference of colour.

The insects are not only provided with abundant means of defence—they are equally well equipped for aggressive warfare. The herbivorous genera, which are by far the most abundant, require, of course, no extraordinary weapons or stratagems for procuring their subsistence; wherever they are called into existence they find the table richly furnished, and their innumerable legions peacefully share in the countless fruits, leaves, blossoms, stems, and roots of the forests and the fields.

The parasitical insects likewise lead an easy life, sipping the juices which others have elaborated, and indolently quaffing at perennial fountains; but the case is very different with the predaceous insects, which, like the carnivorous quadrupeds and birds of prey, can only maintain themselves by artifice or violence, by swiftness or patience, and, after long delays and exertions, are frequently only rewarded with a meagre repast. Yet no soldier enters the field better equipped than they; and though they have greater trouble in obtaining their food than their herbivorous or parasitical relations, they are amply rewarded by the pleasures of the chase. Many, like the carabi and cicindelæ, have strong muscular legs, which enable them to overtake their prey, before it can conceal itself in some crevice; others, like the numerous genera of the hydrophili and dytisci, trust to their expertness in swimming; while others again, like the libellulæ, cleave the air with lightning-like rapidity.

Many are provided with venomous stings, or with a poison ejected through the mandible, so that their bite is fatal; in others, the forefeet are converted into admirable instruments for the seizure of their prey. Thus, in the common gyrinus or water-flea, these members are much longer than the hind-legs, and seize the smaller aquatic animals with the same dexterity and force as the claws of the crab. In the mantidæ they are developed to an enormous length, and formed in such a manner that the tibia closes like a clasp-knife, on the sharp edge of the thigh. Thus armed, the mantis, like a cat approaching a mouse, and under the cover of her leaf-like disguise, moves almost imperceptibly along, and steals towards her prey, fearful



Mantis.
(Mantis religiosa.)

of putting it to flight. When sufficiently near, the forelegs are darted out to their full length, and, suddenly closing on their unfortunate victim, cut it into two, as if it had been mowed with a scythe.

The larva of the ant-lion, an insect which, in its perfect state, bears no inconsiderable resemblance to a small dragonfly, has long been famous for the manner in which it obtains its food. Though totally unfit for the chase (as only the hinder pair of its very feeble legs are employed for locomotion, and these can only drag it slowly backwards), yet its industry in excavating the pitfalls, which are without a parallel in the animal kingdom, enables it fully to supply the want of speed, and to triumph over the most active insects. Depressing the end of its abdomen, and crawling backwards in a circular direction, it traces a shallow trench in some sandy spot, where the soil is as free as possible from stones, and continues this motion until it reaches the centre, scooping up the sand all the time with its head, and jerking it over the margin of the trench; nor does it rest in its labours until it has at length completed a smooth-sided conical pit, varying from one to three inches in diameter at the top, and gradually tapering to the bottom. In the course of its labours it frequently meets with small stones; these it places upon its head, one by one, and jerks them over the margin of the pit. If the weight happens to be too considerable, a new plan is adopted; for, poising the stone upon its back, it carefully walks up the ascent, with the intention of depositing its burden outside the margin. But it not seldom happens that, before it reaches the top, an unfortunate stumble or a jolt mocks the efforts of the little Sisyphus, and sends the liliputian rock to the bottom of the precipice. Any less patient workman would abandon the case as hopeless; but the ant-lion is not so easily disheartened, and has been seen six times patiently to renew his attempts, until at last his resolution was rewarded with success. It is only when the task is utterly impracticable that the persevering engineer at length gives in, and, leaving his half-finished pit, seeks a more favourable spot for the formation of another.

When all obstacles are overcome, and the work is completed, the ant-lion, eager to reap the fruits of his labour, now takes his station at the bottom of the pit, and, to avoid scaring his

intended victims, buries himself entirely in the sand, with the exception of the points of his expanded mandibles. It is not long before some curious ant or inquisitive *little beetle* approaches the yawning abyss; but no sooner does it step upon the margin of the pit, than the treacherous sand gives way under its feet; its desperate struggles only hasten its descent, and, rolling down the yielding sides of the pit, it is precipitated headlong into the jaws of its concealed devourer.

Sometimes, when a more powerful insect chances to fall into the pit, the ant-lion does not obtain a meal on such easy terms, and a regular battle ensues; the victim, in its furious endeavours to escape, bringing down the sand in torrents, which the ant-lion, to avoid being overwhelmed, flings up again as fast as he can. During this conflict a fortunate shower of sand striking the intended prey may knock it over, and bring it within reach of the devourer's terrible jaw, or it may give over through sheer fatigue; but sometimes, the pit gradually filling up, and rendering the slope of the sides shallower, it succeeds in making its escape from the den, leaving the baffled 'ogre' to mourn over the desolation of his shapeless and ruined dwelling.

Though it does not dig an artificial pitfall, the larva of the tiger-beetle catches its prey in a somewhat similar manner. It lives in perpendicular burrows, about a foot in depth, which it is able to traverse with great rapidity, and which are only just of sufficient diameter to permit the inhabitant to pass up-and-down; ascending to the upper portion of its burrow by means of the pair of bent hooks that rise from a humplike projection on the lower part of its back, and then laying its jaws level with the soil. While in this attitude it is almost invisible, and as soon as an insect passes by the ambushed larva the sickle-like jaws grasp it, and it is dragged to the bottom of the tunnel, where it is devoured. Not only is the larva carnivorous, but it is combative in proportion to its voracity; so that if a straw be thrust into its burrow, it will fasten upon it with the obstinate fury of a bulldog, and suffer itself to be dragged out of its home rather than let go its supposed enemy. The burrow, which is the larva's own work, costs it both time and trouble; the earth being loosened by means of the feet and jaws, and then carried to the surface or the flattened head.

Of the insects it may truly be said that the part they play in

the household of Nature seems quite out of proportion to their minute size, and that, though small in body, the miseries they inflict on mankind are on a truly gigantic scale. They destroy and devastate our dwellings, our fields, our meadows, our gardens, and our forests: they feed upon our winter-provisions, they devour our clothing, they attack our libraries, they torment or even kill our cattle; and, not content with all these various attacks upon our property, they even venture to assail our persons, as if to mock our pretensions to the lordship of the earth!

The celebrated entomologist Ratzeburg enumerates 650 species of insects injurious to the forests of Germany alone, and this number may give us some idea of the innumerable hosts which prey upon the vegetable kingdom all over the world. In all their organs, in every stage of their development, the children of Flora are attacked, or even utterly destroyed, over vast tracts of territory by these omnivorous and ubiquitous creatures.

Locust-swarms often change miles and miles of fruitful fields into a dreadful desert. In the year 1773 the larvæ of the bostrychus xylographicus, or the typographer-beetle, of which about 80,000 were collected on a single tree of moderate size, destroyed above two millions of firs on the Harz mountains; and in the year 1479, the cockchafers were so numerous in Switzerland that they caused a famine, and having been cited before the ecclesiastical court of Lausanne to answer for their misdeeds, were excommunicated by their enlightened judges!

These few instances suffice to show how destructive the immense multiplication of the herbivorous insects may become: and when we consider how many millions of tiny mandibles are continually at work, grinding, sawing, cutting, maiming, and devouring all plants, from the most humble grasses to the stateliest trees, we well may wonder how in spite of such attacks our forests still bear such shady canopies, and our fields and meadows such plentiful harvests.

But Providence, which so admirably maintains the balance throughout the whole economy of the organic world, and commands the tides to go thus far and no farther, has also set limits to the ravages of the herbivorous insects. A rainy and changeable spring is alone sufficient to sweep away countless myriads of larvæ while casting their skin, and thus rendered more sensitive

Many species chiefly attack such plants as are already diseased, and by hastening their destruction promote the growth of a more vigorous generation.

An innumerable army of dung-beetles and stercoraceous flies, of ants and termites, is constantly at work, removing the decaying substances which would otherwise pollute the atmosphere; and even the gnats and mosquitos, whose bristly stings inflict such misery upon man, are in another respect his benefactors, as their larvæ cleanse the stagnant waters of the swamps and morasses, and thus prevent many noxious exhalations.

The existence of numerous birds and quadrupeds depends upon that of the insects, which are their exclusive food; and if the caterpillars often prove a source of great annoyance to the gardener, we must not forget that were the insects removed, the nightingale, the redbreast, and other delightful songsters of the fields and groves would likewise perish.

Thus the insects indirectly contribute to our enjoyments, and several of them are of such direct importance as to play a considerable part in the annals of commerce. The silkworm, the cochineal, and the bee enrich whole nations, and give employment to numberless artisans. The gallnuts, a not unimportant article of trade, are produced by the sting of a wasp (*Cynips tinctoria*) on the leaves of the gall-oak; and the

punctures of the manna-fly on the bark of the manna-ash, cause, in a similar manner, a sugary exudation extensively used in medicine.

Many savage tribes live partly upon insects; the termites and several of the larger species of ants are considered a delicacy; and the Bushman and the Bedouin of the desert hail with delight the approach of the locust-swarms which fill the husbandman with dismay. Insects are also used as ornaments. The golden elytra of the sternocera chrysis serve to enrich the embroidery of the Indian zenana; and the ladies in Brazil wear necklaces composed of the green-and-azure wings of lustrous chrysomelidæ, whose brilliancy rivals the costliest gems in beauty.

Thus the insects gratify in various ways the wants or the vanity of man; and if they frequently prove a source of annoyance or even of loss, it is in many cases only the well-deserved punishment of human cruelty or folly. Thoughtlessly he destroys the innocent mole, the devourer of countless grubs—the bat, whose eager appetite cleanses the land of moths and cockchafers; nor does he spare even the lovely songsters of the groves, that not only charm us with their notes, but are constantly at work preventing the dangerous increase of the herbivorous insects.

Insect life gives us the most convincing *proofs not only of* the wisdom and power of the Almighty, but also of *His ineffable* goodness; for these numberless species, so variously gifted, have all been born for a far greater share of happiness than of sorrow. The pangs of death are generally short—a fleeting moment; while their life, which, at least in the larval state, is frequently prolonged during several years, is almost entirely devoted to agreeable occupations. When a caterpillar is feasting on a succulent leaf, or a bee is sipping the nectar of a flower, they are surely enjoying life; and who can doubt of the happiness of a swarm of gnats maintaining for hours together their dances in the air, or of the butterfly lightly hovering through the forest-glades in the warm sunshine? The hum of the beetle and the shrill tone of the cicada, the cricket's chirp, and the buzz of the bee give expression to sensations which are evidently of no gloomy nature; and as every moderate exertion of our mental or bodily faculties calls forth agreeable feelings, we can be well assured that the rapid course of the tiger-beetle, the

prodigious leap of the grasshopper, or the aërial velocity of the dragonfly are continual sources of enjoyment for these active little creatures. Thus every tree, every shrub, every flower by the roadside is the residence or the food of numbers of tiny beings to whom existence is a pleasure. We surely do not require the dryads or the nymphs of the ancients to animate our groves and fields, or to lend a voice to dumb Nature; the aid of mythological fictions is superfluous where such an exuberance of life bursts forth from every plant, and sings the praises of the Creator. As soon as the morning sun gilds the summits of the mountains, millions of insects awake and stretch their limbs, or expand their wings to enjoy the light of day; the evening calls forth new legions from the shady recesses of the forest, and even the dark night rejoices in children of her own.

In the glowing noonday heat of summer all nature seems indeed to sleep: the birds are silent, and the wild beasts of the forest retire to their lairs; but even then an attentive ear is still able to distinguish among the shrubs and herbage the low confused hum of numberless insects. Thus at all hours their voices eloquently proclaim the universality of life, and the grandeur of the Deity from whom all life proceeds!

On surveying the distribution of the two great divisions of the insect world over the face of the earth, we find new reasons to admire His wisdom and beneficence. Thus in the loftier Alps, where the growth of trees is reduced to stunted proportions, but where the meadows are still covered with a variety of beautiful sweet-scented flowers, and afford the finest pasture to numerous herds, the species of the carnivorous insects are at least four times more numerous than the herbivora, many of which do not ascend into the higher regions. This predominance of the former is evidently intended to keep in check the enemies of vegetation, which at this considerable elevation, where the summer is but short and insectivorous birds are rare, requires a greater protection than in the lowlands. Supposing the proportion reversed, then the Alpine meadows would no longer be able to sustain those numerous herds which are the pride of Switzerland; and regions which now largely contribute to the welfare of the human race would lose a great part of their value, and be converted into the worthless feeding-ground of a lower class of animals.

In the insect world the wonders of instinct may truly be said to have reached their highest development, as if Providence had wished to indemnify these little creatures for their want of physical strength by the sharpening of their intellectual faculties. Like the protecting ægis of Minerva, instinct preserves the insect from a thousand dangers, teaches it to seek its food in the most profitable manner, accompanies it throughout the various phases of its life, watches over the infant brood, and even compels the individual to subordinate his whole existence to the welfare of the state or community of which he forms a part.

How beautiful is the care which the insects bestow upon their progeny!—how admirable the instinct which teaches them to lay their eggs in those places where the larvæ as soon as they come forth are sure to find the most appropriate food!

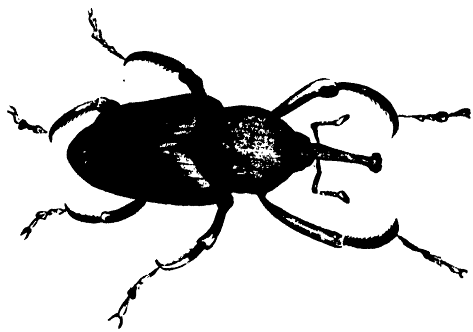
At the beginning of August, when the fruits of the nut-tree are still young and tender, the nut-weevil (*Balaninus nucum*) pierces the soft rind with her long slender snout, deposits her egg in the puncture, and continues this operation until her whole provision is exhausted. The nut, being but slightly injured, continues to grow and ripen for the benefit of the larva, which feeds deliciously upon the kernel in which it is imbedded. When in autumn the nut drops upon the ground, it creeps out of its snug little nursery, and immediately burrows into the earth, where it assumes the pupa state, and in the following summer comes forth as a perfect insect.

Another species of rynchophorous insects, the rynchites auratus, seeks the sunny side of an apple, detaches a small piece of the skin, lays an egg in a little hole which it hollows out, and then covers it again so carefully with the detached rind that it is almost impossible to find out the place. The larva does not live upon the fleshy part of the fruit, but bores its way to the kernels; and after having devoured them again pierces the apple, and dropping down undergoes its pupal transformation in the earth.

The rynchites betulæ divides the borders of the birch-leaves in a most artistical manner, so as to be able to roll them up into a funnel, in which it deposits an egg. At the same time it also partially cuts through the middle rib of the leaf, so as to cause it gradually to wither. When the larva comes forth, it thus

finds the dried leaf-substance on which it feeds ready prepared for its use; and after having exhausted its stores, drops down to seek a new refuge in the bosom of mother earth. The rynchites betuleti, which is very destructive in the vineyards of the Rhine and the Moselle, is equally clever in rolling together several of the top-leaves of a branch like a cigar, by covering their borders with a glutinous substance, and then smoothing them down with the hind-part of its body.

A great number of similar examples might be cited among the rynchophorous insects alone, of which more than 7,000



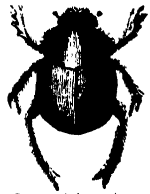
Calandra longipes.

species have already been described by entomologists: but not to tire the reader I shall merely remark, that wherever they deposit their eggs, in blossoms or in leaves, in fruits or in seeds, in branches or in roots, it is always done with the same admirable prevision, as if they were endowed with an intuitive knowledge of the development of vegetation and the progress of the seasons.

The dung-feeding lamellicorns provide in a different but no less ingenious manner for the future wants of their progeny, by rolling balls of excrementitious matter in which they enclose their eggs. These balls are at first irregular and soft, but by degrees, and during the process of rolling along, become rounded and harder; they are propelled by means of the hind-legs; and the insects occasionally mount to the top when they find a difficulty of urging them along, probably in order to destroy the equilibrium. Sometimes these balls are an inch and a-half or even two inches in diameter, and in rolling them along, the

beetles stand almost on their heads, with their heads turned from the balls. These manœuvres have for their object the burying of the balls in deep holes, which the insects have previously dug for their reception, and it is upon the dung thus deposited that the larvæ when hatched feed.

Sheltered from the frosts of winter in their subterraneous retreats, they lead a life of darkness in the midst of the abundance which the labours of their parents have stored up for their use; but as soon as warm spring knocks as it were at their door, to invite them to exchange their gloomy abodes for the light of day, they eagerly creep forth in a more perfect form to enjoy the cheerful rays of the sun, and to labour in their turn for the wants of a new generation. On account of this provident care for its young, the 'Ateuchus sacer' was revered by the ancient Egyptians as one of their sacred animals, and its image, carved in stone or metal, is frequently found rolled up in the mummies of that remarkable race.



Sacred Beetle.
(Ateuchus sacer.

The necrophori, or sexton-beetles, inter in a similar manner the bodies of small animals in which they lay their eggs. During the day they are generally quiet, but in the evening they begin to be active. To dig a hole, and then to drag the bird or mouse they may have selected as the object of their labours into it, would be a task far beyond their powers, and they therefore employ another plan. They entirely burrow beneath the carcase, emerging every now and then to scrape out the loose soil, walk round it, mount as if to see how the work is proceeding, and then disappear afresh and renew their labours until the hole is large enough to allow the bird to sink into the required position. The time occupied in the transaction naturally varies according to the size of the object, the number of the labourers, and the nature of the soil; but, on an average, an ordinary finch or a mouse can be buried in the course of a day. When the task is completed, a number of eggs are laid upon the buried animal, and then the beetles emerge, cover it with earth, and fly away.

Necrophorus vespillo.
(Sexton or Burying-beetle.)

Astonishing but well-authenticated accounts have been given of the sagacious industry with which these little creatures accomplish labours which must be to them enormous. They will bury not one but a whole series of corpses; and in the well-known experiments of Mr. Gleditsch, four beetles buried in a small piece of earth four fishes, three birds, two grasshoppers, one mole, the entrails of a fish, and part of the lungs of an ox. Now the mole is at least forty times as large as the beetle, so that we can estimate the strength and perseverance of the beetle by calculating the labour which would be necessary for a man to inter in two days an animal forty times as large as himself.

But these indefatigable insects are remarkable not only for their industry but also for their intelligence, of which truly surprising instances have been observed.

Thus Clairville once saw a sexton-beetle, which, finding a dead mouse too heavy to be removed, flew away and soon after returned with four others, who with united strength now dragged away and buried the mouse.

Gleditsch relates that one of his friends being desirous to dry a toad tied it to the upper end of a stick, which he fixed in the ground to prevent the necrophori from getting hold of it. But this precaution proved perfectly vain; for the intelligent insects, finding the toad beyond their reach, dug up the earth round the stick, and having thus caused it to fall, buried it together with the toad.

The same intelligence was shown by a dung-beetle (*Gymnopleurus pillularius*), who being unable to move a stercoraceous ball on which he had been labouring from a hole into which it had fallen, immediately flew to a neighbouring heap of dung, whence he fetched three other beetles, who having lent their assistance returned to their own work.

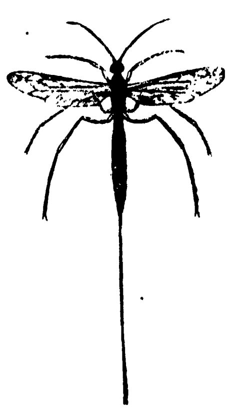
Like their parents, the larvæ of the necrophori live only upon animal substances, so that the mother has merely to provide her offspring with the food she relishes herself; but in other cases we find, by a still more astonishing instinct, insects herbivorous in the perfect state supplying in a similar manner the wants of their carnivorous larvæ.

In her full-grown state the sand-wasp (*Sphex*) lives upon the nectareous secretions of flowers, but her larvæ have a far grosser appetite, and, like the meat-fly, delight in sipping animal juices.

Who would not expect that the mother, judging of her offspring's appetite by her own, would set before them her favourite dainties of roses or apple-blossoms? But she *is taught that* her little ones have a far different taste; and thus, after having dug a hole with her forefeet, scratching the earth like a terrier in pursuit of a mouse, she fetches a spider or a caterpillar, and, not seldom after a hard scuffle, drags her victim to the grave she has provided for its interment. She bites it in the neck, so as to paralyse its resistance, but takes good care not to kill it; and having laid a single egg upon its body, covers it up and flies away.

The maggot on creeping forth immediately bites a hole in the body of the spider, which her mother—a disinterested assassin! —had wounded for her sake, and begins to suck the juices of the victim with the same eagerness as a leech feasting on human blood. In a few days the exhausted spider expires, and then the maggot devours the flesh and skin, leaving nothing but the hardest parts untouched.

The ichneumon-fly does not give itself the trouble to overpower the victims destined for the food of its larvæ, and to drag them away to a subterraneous den, but follows the easier plan of depositing its eggs in the bodies of other living insects, particularly those of caterpillars. For this purpose many species are provided with a strong and sharp abdominal tube or ovipositor, which is used to insert their eggs in the bodies of caterpillars that live beneath the bark or crevices of wood. This is generally long, and capable of piercing almost any substance; while such as have a short ovipositor place their eggs in or upon those caterpillars to which they have easy access.


Ichneumon-fly. (Pimpla persuasoria.)

Some which select the eggs of butterflies for the residence of their ova are so small that they are scarcely perceptible with the naked eye, while others again from their size and strength are formidable even to the large spiders, destroying them with their powerful stings. Some place their eggs within the aurelia of a nascent insect—others deposit them within the nest which

the wasp has contrived for her young; and as both are produced at the same time, the offspring of the ichneumon not only devour the young wasps, but also the whole supply of larvæ which the parent had carefully provided for their support.

Thus these active flies, which in their perfect state feed solely upon the juices of flowers, render almost the whole of the insect world tributary to the wants of their larvæ; and as Germany alone possesses above 5,000 species of ichneumonidæ, it may easily be imagined how terrible they must be to the other insect-tribes, and consequently also how useful to mankind, by their destruction of myriads, which would otherwise be left to banquet on the fruits of the earth! The ichneumon larvæ, thus born in a living body, subsist on the juices of their victim, but without absolutely destroying it—in fact, the animal they infest may continue to live for some time, thus affording them a continued supply of nutriment; but when the ichneumons are ready to undergo their last metamorphosis, they pierce the skin of their now useless victim, and each, spinning itself in a small oval case, changes into a chrysalis—the whole number forming a group on the shrivelled body of the unfortunate caterpillar.

The œstri or breeze-flies likewise deposit their eggs in or upon living animals, but instead of choosing, like the ichneumon-flies, other insects for their victims, they ambitiously select large quadrupeds for the future provision of their young—each species almost invariably confining its attacks to a certain species of animal. The larvæ of the equine breeze-fly, or *bot* as it is usually termed, can only be developed in the stomach of the horse, and it may well be asked how they are able to reach these hidden pasture-grounds, so indispensable to their existence. But Providence has found the way by teaching the breeze-fly to deposit her eggs on those parts of the horse's body which are most likely to be nibbled by the animal. When the eggs have remained on the hairs four or five days, they become mature, after which time the slightest application of heat and moisture is sufficient to bring forth in an instant the latent larva.

At this time if the lips or tongue of the horse touch the egg, its operculum is thrown open, and the young larva liberated; which readily adhering to the moist surface of the tongue, is from thence conveyed with the food to the stomach, when it

has full leisure to acquire maturity. Having attained this object, it abandons the dwelling of its youth, and falling to the ground, soon finds a convenient retreat for undergoing its change into a chrysalis.

Generally the insects, after having once provided for the future wants of their progeny, by laying their eggs on (or in) such substances as will afterwards afford them a fitting sustenance, take no further care of them ; yet many instances may be adduced, in which they give marks of a real parental affection. Thus the earwig sits on her eggs in the manner of a hen until they are hatched, and then continues to brood over her young with affectionate assiduity, continuing frequently in the same sitting posture for hours, allowing them to push her about, and cautiously moving one foot after another, for fear of hurting them. Baron de Geer, a distinguished pupil of the celebrated Linnæus, finding one in this position, removed it into a box, in different parts of which he scattered the eggs. The mother, however, speedily gathered them in her jaws into a heap, and sat on them as before.

A species of field-bug (*Cimex griseus*) brings up her family, which generally consists of thirty or forty young, leading them about as a hen does her chickens, and never leaving them for a moment.

De Geer having once, with all the cruelty of an inquisitive naturalist, disturbed one of these happy families, which had settled upon the branch of a birch-tree, the mother showed every symptom of excessive uneasiness, and far from attempting to escape from her tormentor, who to her must have seemed a terrible monster, continued close to her little ones, incessantly flapping her wings as if to preserve them from danger.

Many insects are not satisfied with burrowing holes, in which they deposit their eggs, but evince a remarkable architectural skill in building cells for their reception. Thus the mole-cricket forms a cavity of clammy earth, in which she deposits about 150 eggs; this nest, which is about the size of a common hen's egg, is carefully closed up on every side, as well to defend its contents from the injury of the weather, as to guard them from the attacks of common beetles; which, being themselves underground inhabitants, would certainly, but for this precaution, either devour or destroy them.

Nothing can exceed her care in the preservation of her young. Wherever a nest is situated, fortifications, avenues, and entrenchments surround it; there are also numerous winding byways which lead to it, and a ditch encompasses the whole, which few insects are capable of passing. But the diligence of these little animals does not end here: at the approach of winter, they move their nests entirely away, and sink them deeper in the ground, to prevent the frost from retarding the progress of their young brood to maturity. When the weather grows milder, they raise their habitations in proportion, till at last they are brought as near the surface as possible without being wholly exposed to view, in order to receive the genial influence of the sun; but should the frost unexpectedly return, they again sink them to their former depth.

The Pelopæus or Dirt-dauber constructs earthen cells, arranged

Nests of the Trypoxylon and Pelopæus.

side by side, which it sticks on walls and rafters; and the Trypoxylon figulus makes similar nests, with necks so very narrow in proportion to their size, and the rim so neatly turned over, that the work would do credit to the most skilful potter.

Several other genera of wasps and bees are remarkable for their clay-built constructions; but the manner in which the

Megachilæ or Leaf-cutters form their nests, is still more admirable. After the insect has bored a hole of suitable dimensions in some old tree, she sets off in search of the materials for the cells, and mostly betakes herself to a rosebush or laburnum. Her process, in cutting the pieces of leaf that compose her nest, is worthy of attention. Nothing can be more expeditious—she is not longer about it than we should be with a pair of scissors. "After hovering for some moments over a rosebush, as if to reconnoitre the ground, the bee alights upon the leaf she has selected, usually taking her station upon its edge, so that the margin passes between her legs. With her strong mandibles she cuts without intermission in a curve-line, so as to detach a triangular portion. When this hangs by the last fibre, she balances her little wings for flight, lest its weight should carry her to the ground, and the very moment it parts from the leaf, flies off with it in triumph; the detached portion remaining bent between her legs, in a direction perpendicular to the body. Thus without rule and compass do these diminutive creatures mete out the materials of their work, into portions of an ellipse, in ovals or circles, accurately accommodating the dimensions of the several pieces of each figure to each other. What other architect could carry, impressed upon the tablet of his memory, the entire idea of the edifice which he has to erect, and, destitute of square and plumb-line, cut out his materials in their exact dimensions without making a single mistake? Yet this is what a little bee invariably does!"*

The fashion after which she arranges her nest is equally curious. Bending each leaf into a curved form, she presses them successively into the burrow, in such a way that they fit into one another, and form a small thimble-shaped cell. At the bottom of the cell she places an egg and some bee-bread, a composition of pollen and honey, and then sets to work upon another cell; and in this manner she proceeds, until she has made a series of cells, some two inches in length. The leaves are adjusted together so admirably, that although not covered with any coating of gum, they are honey-tight.

The tunnels of the carpenter-bees are likewise most wonderful instances of instinct. When the little architect has fixed upon a piece of wood which suits her purpose, she first bores

* Kirby and Spence's Entomology.

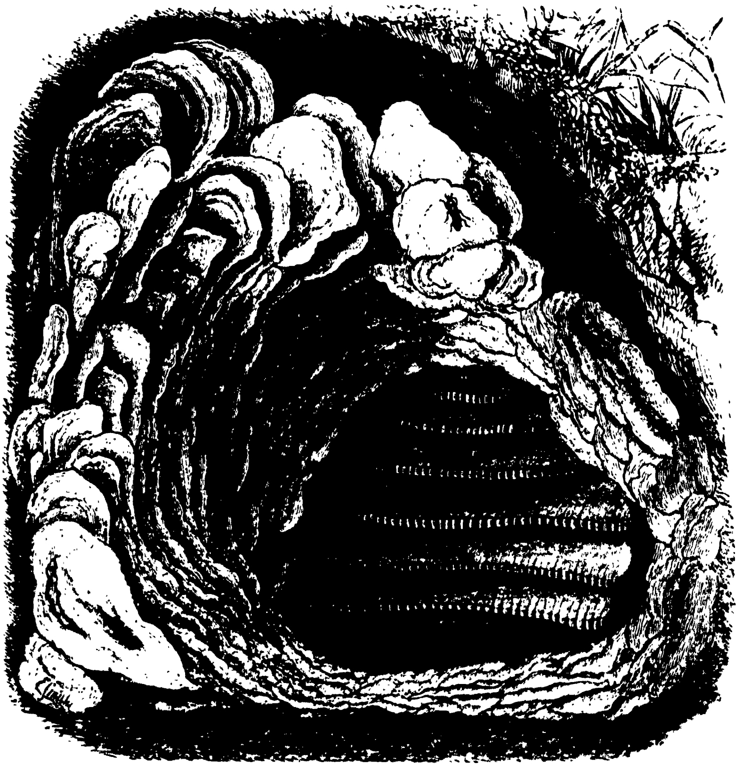
a circular hole, in a horizontal direction, and large enough to allow her to pass; then turns at an angle, and drives her tunnel, frequently above a foot long, parallel to the grain of the wood, and with a passage at the lower end similar to the entrance at the top. None of the detached fragments are wasted, but all are carefully laid aside in some sheltered spot. The tunnel being completed, the industrious bee now sets forth in quest of honey and pollen, and making a little heap at the bottom of the excavation, deposits an egg upon the store. Over this she then proceeds to build a ceiling, which shall be also the floor of another cell.

Carpenter Bee.

For this purpose she goes off to the magazine of wood-chips, which she has laid by with such provident care, and cementing them together with a glutinous substance, probably secreted by herself, fixes them in a ring, above the heap of pollen. A second ring is then placed within the first, and so on, till the flat ceiling is completed. In this manner at least a dozen compartments are made, one above the other, and all completed by the mandibles alone, which are admirably formed for the purpose of working out the tunnels required—being short, stout, and usually furnished at the tip with two teeth, which are rounded somewhat into the form of cheese-cutters. These, when brought into operation, cut out the wood in the same way as a carpenter's double gouge, the teeth being more or less hollowed out within. When the larvæ are full-grown, they assume their pupa state, head downward, so as to allow the oldest and lowermost to make its way out of the bottom of the burrow as soon as it becomes winged, an event which consequently takes place earlier than in those which occupy the upper cells.

If all these burrows and buildings in earth and wood, this leafy tapestry made by single insects, may well be called masterpieces of animal industry, what terms must we use to express our admiration of the labours of the sociable wasps, bees, ants, and termites, the mysteries of whose architectural instinct human understanding is utterly unable to fathom! Implicitly

obeying the laws which Divine Providence has engrafted in their little brain, these truly wondrous creatures devote their whole life to the welfare of the next generation; and either to protect the young from the inclemencies of the weather and the assaults of their enemies, or to secure the provisions



which they accumulate for their use, build or raise, by the united efforts of many thousands, habitations which equal the most artificially-constructed birds' nests, or even surpass them by the complication and mathematical precision of their structure!

To add to the wonders of these marvellous buildings, it should be remembered that the species of their constructors are very numerous, each species indulging in its own modifications of

architecture—some rearing their palaces in caves, others suspending them from trees; some covering them with domes, others attaching them to roofs or rafters; so that we have here, not three or four, but a whole series of insect-towns, varying according to circumstances, but in each case impressed with the stamp of perfection.

Among the various structures of the social wasps, one of the most interesting is that of the *Chartergus nidulans*, a native of

Nest of Chartergus Nidulan

America, which is formed of a beautifully-polished white and solid pasteboard, impenetrable by the weather. These nests are pendulous, and attached to branches of trees; the hole through which the branch is passed being very large, so as to permit the nest to swing freely in the wind. The dimensions are extremely variable, from a few inches to several feet in length, each structure appearing to be capable of unlimited enlargement; for when the increasing population of the commonwealth renders additional accommodation necessary, the little architects, taking the bottom of the nest as the starting-point, build upon it a new series of hexagonal cells, opening downwards, as in most other nests constructed by the Vespidæ. At each enlargement of the colony, they take care to add another row or two to the circum-

ference, so as to increase the diameter in proportion to the length; then fresh material is added to the outer wall, which is lengthened so as to include the new tier of cells; and thus the bottom is closed with a new floor (about half an inch distant from the opening of the cells), which in its turn will become the ceiling of the next storey. Each of the combs which thus rise tier above tier in the cavity of the bell-shaped nest, has a central hole, through which access is obtained to the uppermost stories of the edifice; and though darkness reigns within, yet such is the instinctive order which prevails, that thousands move about without one disturbing the other.

The history of the wonderful domestic economy of the hive-bee has been too often described, and is too well known to be repeated here; whole volumes have been written on the subject without exhausting its mysteries, many natural philosophers have devoted half their lives to its study, and yet every new observer finds occasion to point out some fresh marvel in these wonderful annals. Indeed, the whole life of these little creatures is nothing but a continued series of wonders.

When we consider that the family of ants, undoubtedly the most numerous of any in the whole circle of winged insects, spreads in several thousands of species over almost every part of the habitable globe, and that each species delights in its own modifications of structure, we cannot wonder that the architectural details of these insect-cities are but imperfectly known, (particularly when we bear in mind that most of them are situated in the wilds of the torrid zone, which are frequently all but inaccessible to the naturalist, and that they are moreover extremely well-guarded by the formidable mandibles or pungent stings of their builders); yet from the little we do know of them, there can be no doubt that they occupy a high rank among those homes without hands, which animal instinct rears as so many monuments of Divine goodness and wisdom.

Some form globular nests (of the size of a large Dutch-cheese) of small twigs artistically interlaced; others use cotton, and through the chemical agency of their pungent secretions convert it into a spongy substance. Other species, still more ingenious, construct their domicile out of a large leaf, bending the two halves by the weight of united thousands, till the

opposite margins meet at the under-surface of the midrib, where they are secured by a glutinous matter.

ests of the Fi

The Coushie or Sauba Ant, which exists in Tropical America in boundless profusion, will in a very short time strip off the leaves of an entire field and carry them to its subterranean abodes. Even where their nest is a mile distant from a plantation, these depredators know how to find it, and soon form a highway about half a foot broad, on which they keep up the most active communications with the object of their attack. In masterly order, side by side, one army is seen to move onward towards the field, while another is returning to the nest, each individual carrying in its jaws a circular piece of leaf, about the size of a sixpence, which is held vertically by one of its edges—a circumstance from which the creature is also called the parasol or umbrella ant. If the distance is too great, a party meets the weary carriers halfway and relieves them of their load. Although innumerable ants may thus be moving along, yet none of them will ever be seen to be in the other's way, and all goes on with the regularity of clockwork. A third party is no less actively employed on the scene of destruction, cutting out circular pieces of the leaves, which as soon as they drop upon the

ground are immediately seized by the attentive and indefatigable carriers.

The use of the leaves is to thatch the domes of their curious edifices, and to prevent the loose earth from falling in. Some of these domes are of great size, measuring two feet in height and forty feet in diameter; and yet they are still far surpassed in extent by the subterranean galleries which these industrious little creatures form, and whose extent may be conjectured from the fact, that when sulphur-smoke was blown into a nest, one of the outlets was detected at a distance of twenty yards. Division of labour is carried out to a wonderful extent in these buildings, for the labourers which gather and fetch the leaves do not place them, but merely fling them down on the ground, and leave them to a relay of workers, who lay them in their proper order. As soon as they have been arranged, they are covered with little globules of earth, and in a very short time they are quite hidden by their earthy covering

These structures, however wonderful, are far surpassed by those of the termites. Their cone-shaped or domelike edifices rise to the height of ten, twelve, or even twenty feet, with a corresponding diameter; and although made merely of clay, which the termites excavate with their mandibles from a considerable depth underground, moistening it with tenacious saliva, their strength is such that hunters are accustomed to mount upon them for the purpose of looking out for game; and even the intense rains of the monsoons, which no cement or mortar can long resist, fail to penetrate their surface. Only the underpart of the mound is inhabited by the white ants, the upper portion serving principally as a defence from the weather, and to keep up in the lower part the warmth and moisture necessary to the hatching of the eggs and the cherishing of the young ones. In the centre and almost on a level with the ground is placed the sanctuary of the whole community—the large cell, where the queen resides with her consort, and which she is doomed never to quit again, after having been once enclosed in it by her faithful subjects, since the portals soon prove too narrow for her rapidly-increasing bulk. Encircling the regal apartment extends a labyrinth of countless chambers and nurseries, all connected by arched galleries, long passages, and doorways of the most intricate and elaborate

constructions. The subterranean passages which lead from the mound are hardly less remarkable than the building itself. Perfectly cylindrical, and lined with a cement of clay similar to that of which the hill is formed, they sometimes measure a foot in diameter. They run in a sloping direction under the bottom of the hill, to a depth of three or four feet, and then ramifying

Mounds of the Termites.

horizontally into numerous branches, ultimately rise near to the surface at a considerable distance. At their entrance into the interior of the hill, they are connected with a great number of smaller galleries, which ascend the inside of the outer shell in a spiral manner, and winding round the whole building to the top, intersect each other at different heights, opening either immediately into the dome in various places, and into the lower part of the building, or communicating with every part of it by other smaller circular passages.

If the colossal structures of the termites are worthy of our highest admiration, our wonder increases when we consider that all these labours are performed in total darkness, for the astonishing little animals are constantly working underground.

CHAPTER XXIII.

SPIDERS

Venomous Apparatus—Spinnarets—The Spider's Web—*Patience of the Spiders*—Hunting Spiders—Trapdoor Spiders—Water Spiders—*The Raft Spider*—Enemies of the Spiders—Fecundity—Maternal Affection—The Stalita *Tænaria*.

INCAPABLE of muscular exertion, and of a texture so loose and soft as to be torn to pieces or crushed by the slightest degree of force, the spiders seem exposed to every attack; and yet, helpless and harmless as they appear to be, they are able to subdue animals much larger than themselves; for as a compensation for their weakness, they are endowed with a most admirable industry, an exemplary patience, an indomitable perseverance, and the power of secreting two liquids which fully answer all the purposes of offence or defence which their mode of life requires. One of these liquids is a poison which at once paralyses the resistance of their prey, and acts with the same instantaneous and fatal effect upon a fly or a beetle as prussic-acid on the human economy; the other, a glutinous fluid, which, concreting in the air, forms those silken threads which their wonderful instinct turns to so many valuable uses.

Spider's Mandible (highly magnified).

The structure of the venomous apparatus of the viper is justly admired, but that of the spider is a no less beautiful piece of mechanism. It is by means of the two mandibulæ or forciples with which their mouth is armed, that they inflict their deadly wound. These mandibles are each armed with a moveable and extremely sharp claw (*a*), near to the point of which is a minute orifice (*b*), from which there escapes a drop of poisonous liquid, that spreads itself over the whole wound the instant that it is inflicted. This orifice, which

is so extremely minute as to require a high magnifying power for its perception, communicates with a fine or narrow excretory canal (*c*) situated in the interior of the mandible, and given off from the true secreting organ—a gland (*d*) lodged in the inter-space of the muscles of the thorax, or breast, whose compression causes the immediate propulsion of the liquid.

A still more wonderful apparatus is that which serves the spiders for the formation of their threads. The spinnarets, or organs which emit the glutinous fluid, are generally six in number, and situated at the posterior part of the body. Each of the spinnarets is pierced by an infinite number of small holes, or beset with hairy appendages terminating in fine-drawn points, from each of which there escape as many little drops of a liquid, which becoming dry the moment it is in contact with the air, forms so many delicate threads. Immediately after the filaments have passed out of the pores of the spinnaret, they unite first together and then with those of the neighbouring spinnarets to form a common thread; so that the thread of the spider, which measures only 1-4000th or even 1-8000th of an inch in diameter, is composed of an immense number of minute filaments, perhaps several thousand, of such extreme tenuity that the eye cannot detect them until they are all twisted together into the working thread.

Spider's Spinnarets (highly magnified).

But why this complicated process, it may be asked; why this original excessive subdivision of a filament, which, when complete, far surpasses in fineness the finest thread which can possibly be spun by machinery proceeding from human hands? The reason is obvious, for it was absolutely necessary that as soon as the glutinous fluid emerged from the body, it should *instantly* consolidate into a thread firm enough to be worked or not to give way too suddenly under the spider's weight; and it is evident that by its extreme division, so beautifully provided for by the microscopical perforation of the sievelike spinnarets, the process of desiccation, having a larger surface to act upon, must be considerably hastened. Thus there is nothing superfluous in this wonderful mechanism, which, perfect in design

and in every detail, could only have been planned and formed by the power and wisdom of God!

On examining the uses to which the spiders put their admirable spinning organs, we shall find in every case the workman worthy of his tools. When a house or common spider is about to form a web, it first selects some commodious and secure spot, where insects appear to be in sufficient abundance. It then distils a small drop of its glutinous liquid, and creeping up the wall and spinning its thread as it proceeds, darts itself in a very surprising manner to the opposite station, where the other end of the web is to be fastened. The first thread thus spun, drawn tight and fixed at each end, the spider runs on it to and fro, still assiduously employed in doubling and strengthening it, as on its force the stability of the whole fabric depends. The scaffolding being thus completed, the spider draws a number of threads parallel to and within the first in the same manner, and then crosses them with others, the adhesive substance of which they are formed serving to bind them together when newly spun. This operation being completed, the industrious little architect doubles and trebles the thread that borders its web, by opening all its papillæ at once, and so secures the edges as to prevent the wind from displacing the work. The edges being thus fortified, the retreat is next to be attended to; and this is formed like a funnel, where the little workman lies concealed. To this there are two passages or outlets, one above and the other below, very artfully contrived to allow the animal an opportunity of making excursions in every direction. Frequently also, from the main web, there are several threads extended at some distance on each side, like the cordage of a ship; this may be considered as the outworks of the fortification, which whenever touched from without, instantly communicate the intelligence by the vibration of the net, and bid the lurking spider prepare for attack or self-defence. If the insect impinging happens to be a fly, the concealed assassin instantly springs forward to pierce it with his murderous mandibles; but if, on the contrary, he perceives an enemy stronger than himself, he then, considering discretion to be the better part of valour, keeps quietly within his fortress, and never stirs till the storm is blown over.

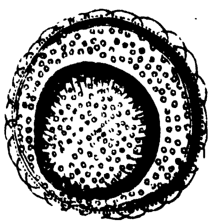
If the web has been destroyed, the spider is able to renew it

twice or thrice from its glutinous stores; but after that its supplies are exhausted, and then it must either die of hunger, or conquer another net, after having defeated the rightful owner in mortal combat; or endeavour to find an empty web, which is not so very difficult, as the young spiders construct two nets.

The Garden Spider, which suspends its vertical or oblique web in open space, works in a different manner. It spins a large quantity of thread, which floating in the air in various directions, happens from its glutinous quality at last to adhere to some object near it—a wall or the branch of a tree. The spider is anxious to have one end of the line fixed, that it may be enabled to secure and tighten the other; it accordingly draws the line when thus fixed, and then by passing or repassing it, strengthens the thread in such a manner as to answer all its intentions. The first cord being thus stretched, the spider walks along a part of it and there fastens another; and dropping from thence, affixes the thread to some solid body below; then climbs up again and begins a third, which it fastens by a similar contrivance.

Within this framework, which unites strength and elasticity in a remarkable degree, and though yielding to the slightest pressure immediately recovers its position, the spider now begins to spin its beautiful network, composed of a number of straight lines radiating from a common centre, and having a spiral line wound regularly upon them.

The radiating lines are smooth, whereas the spiral line is thickly studded with minute knobs, to which the efficacy of the net is due, for they are composed of a thick adhesive and viscid substance, and serve to arrest the wings and legs of the insects that happen to touch the net. It has been observed that these viscid threads are of uniform thickness when first spun, but that undulations soon appear in them, and that the viscid matter soon accumulates in globules at regular intervals.



Sievelike Spinnaret of the Garden Spider.

As the spinnarets of the garden-spider are of a different anatomical structure—one pair presenting on its surface a number of small perforations, the edges of which do not project, and which therefore resemble a sieve, while the other is studded with

hollow tubes perforated at the extremity—*there is reason to* suppose that each kind of thread is produced by its own pair of spinnarets.

Another point in the construction of these webs, so exactly true in all their proportions, is that they are executed entirely by the sense of touch. The eyes are situated on the front of the body and on the upper surface, whereas the spinnarets are placed at the very extremity of the body on the under-surface, the threads being always guided by one of the hind-legs, as may be seen by watching a garden-spider in the act of building or repairing her web. To place the fact beyond a doubt, spiders have been confined in total darkness, and yet have spun webs as perfect as if they had been suspended in the open daylight.


Tubular Spinnaret of the Garden Spider.

All spiders require patience, for they have often a long time to wait before they entrap their prey, and even the garden spiders are subject to long privations, in spite of their consummate skill. Continual stormy weather destroys their nets, and frequently prevents their making a new one for many a day; so that during the protracted period of involuntary fasting, not even a gnat can be caught to satisfy their hunger. And when at length the new net is suspended, a colossal wasp or huge bee comes flying against it, and tears a prodigious breach in its delicate texture. But the philosophic spider bears all the buffetings of adverse fortune with exemplary patience, and instead of breaking out into useless complaints, immediately sets to work, and in a short time the damage is fully repaired.

Besides the netmaking spider, there are many others that are satisfied with less artificial snares for entrapping their prey. Some draw their threads over the surface of a leaf, and thus catch the insects that heedlessly wander over the treacherous ground; others spin them under stones or in the fissures of the soil. In hollow walls, in the crevices of windows, the ferocious Segestria conceals her body in a cylindrical tube, open at both ends, from which only her forefeet project, ready to rush upon her prey. She weaves no web, but merely draws a few threads about the hole in which she has fixed her abode. As soon as an unwary fly touches one of them, she immediately

pounces upon it and seals its doom. Even wasps, which other spiders are averse from attacking, either on account of their sting or of the hardness of their integuments, are fearlessly encountered and defeated by this formidable spider; for its breast and feet are very hard, and the abdomen is covered with a thick skin, so that it does not fear their sting, and its strong and hard mandibles are able to crush their horny coverings. So beautifully is the organization of the spiders modified, according to the various prey which has been destined for their use!

The Salticus scenicus, a common black-and-white spider, which may always be seen in summer upon walls and windows, disdains the use of any snare, and, like the tiger, relies upon his spring alone for the overpowering of his prey. When he spies a fly at a distance, he approaches softly step by step, and seems to measure his distance from it by the eye; then if he judges that it is within reach, first fixing a thread to the spot on which he is stationed by means of his forefeet, which are much larger and longer than the others, he darts on his victim with such rapidity and so true an aim, that he seldom misses it. He is prevented from falling by the thread just mentioned, which acts as a kind of anchor, and enables him to recover his station.

The subterranean labours of the large trapdoor spiders, of which many species abound in the warmer climates, are no less admirable than the nets of the weaving arachnidæ. These hideous brown or black-haired creatures, which sometimes attain a length of three inches, while their legs embrace a circle of half a foot in diameter, dig deep tubular holes in the earth, from which they sally forth after sunset in quest of prey, or to which they retreat in case of danger. The interior of the nest, which is sometimes nine inches deep, is lined with a double coat of tapestry—the one nearest the wall, which is of a coarser tissue, being covered with a pure white silken substance like paper—but it is chiefly in the construction of the trapdoor which secures its entrance that the little architect displays a remarkable ingenuity. This lid is a flap of the same substance as the tube, of a circular shape, so as to fit the orifice with perfect accuracy; and attached to the tube by a tolerably wide hinge, so that on closing it does not fall to either side, but comes true and fair upon the opening which it guards. A curious instinct teaches the spider to make her tunnel in some

Water Spiders.

outer surface of the door being on a level with the ground, and covered with earth taken from the soil in which the tunnel is excavated, it is evident that all traces of the burrow are lost, so that a more perfect hiding-hole cannot possibly be imagined.

By a no less admirable instinct, the water-spider has been taught to fabricate a kind of diving-bell, for which purpose she

usually selects still waters. Her house is an oval cocoon lined with silk, from which threads issue in every direction, and are fastened to the surrounding plants; in this cocoon, which is open below, she watches for her prey, and even appears to pass the winter, when she closes the opening. It is most commonly entirely under water, but its inhabitant has filled it with the air needful for respiration, and breathes as easily in her subaquatic home as if her wonderful nest were suspended in the atmosphere. The manner in which she fills her cell is very curious. She ascends to the surface slowly, assisted by a thread attached to the leaf or other support below. As soon as she comes near the surface, she turns with the extremity of the abdomen upwards, and exposes a portion of the body to the air for an instant; then, with a jerk, she snatches as it were a bubble of air, which is not only attached to the hairs which cover the abdomen, but is held on by the two hinder legs, which are crossed at an acute angle near their extremity—this crossing of the legs taking place the instant the bubble is seized. The little creature then descends more rapidly and regains her cell, always by the same route, turns the abdomen within it, and disengages the bubble. In this way more than a dozen journeys are performed — sometimes two or three very quickly one after another, at other times with a considerable interval between them, during which period the industrious little animal is employed in extending and giving shape to her silvery dome, getting into it, pushing it out at one place, and amending it at another, and strengthening its attachments to the supports. At length, when satisfied with her work, she settles in her den head downwards, and, undisturbed by the wind that ruffles the surface of the pond, lies in wait for her prey, or, having dragged it to her cavern, leisurely devours it.

She also places her eggs in this cell, spinning a saucer-shaped cocoon, and fixing it against the inner side and near the top. In this cocoon are about a hundred eggs, of a spherical shape, and very small. The cell is a true home for the young spiders, who, when sufficiently strong to provide for themselves, are turned adrift by the mother, and, prompted by their wonderful instinct, soon construct a subaquatic home similar to that in which they first drew breath.

The raft-spider is another aquatic or rather semi-aquatic

species ; but instead of living beneath the water, it only makes a temporary and moveable residence on the surface of fens and marshes.

Not content with chasing insects on land, it follows them in the water, on the surface of which it can run freely. It needs, however, a resting-place, and to supply this want it has been taught by instinct to form a kind of raft, by collecting a quantity of dry leaves and similar substances, which it fastens with silken threads. Here it sits, and allows itself to be blown about the water by the wind, ever ready to seize the first aquatic insect that comes within its reach, or to pounce with the rapidity

The Raft

of lightning upon some unfortunate moth or beetle that has fallen into the water, and vainly endeavours to extricate its wings from the uncongenial element. It can even descend below the surface by crawling down the stems of aquatic plants, and this capability of existing some time beneath the water is often the means of saving its life ; for when it sees an enemy approaching it quietly slips under the raft, and remains concealed until the danger has passed.

Thus we find the spiders uniting every mode of attack or variety of warfare—the bold onslaught of the lion, the tiger's

spring, the patient artifice of the lynx, the poison of the adder, and the diving agility of the otter. But if they thus render themselves extremely formidable to the insects, and essentially contribute to keep them within due limits by the destruction they cause among their ranks, they in their turn are exposed to the assaults of numberless enemies. Independently of those which they find in their own class, the centipedes seize them beyond the possibility of escape; while several species of ichneumons and wasps, more savage and poisonous than themselves, will rush upon spiders eight times their size and weight, and benumbing them with their sting, triumphantly bear them off to their nests, to serve as food for their larvæ.

In spite of their citadels, the trapdoor spiders frequently succumb to the ants, the most formidable enemies of their youthful progeny; and while the water-spiders are hunting the aquatic insects, they themselves are chased by the water-scorpions and the larvæ of the dragonfly.

Several species of monkeys, squirrels, lizards, tortoises, frogs, and toads catch and devour them wherever they can. In the islands of the Indian Archipelago we even find several sparrow-like birds, that have been named arachnotheræ, from their living almost exclusively on spiders. Armed with a prodigiously long and arcuated beak, they know how to pursue them and drag them forth from their obscure recesses.

To resist so many attacks which menace their existence, the spiders have been endowed with a variety of passive defences. Their shy and solitary habits are a safeguard against many dangers. Many feign death and thus deceive the voracity of an enemy or the caution of their prey, while others are enabled by their colour to enjoy the advantages of concealment. Thus those that spend their lives in the trees and bushes are frequently green like the foliage on which they dwell, or brilliantly tinted like the gaily-coloured flowers which serve as their abode; while those which are in the habit of frequenting gloomy places appear in a dark-coloured and dingy garb, harmonizing with their dreary mode of life.

An exception to the general rule is, however, found in those large and powerful species, which, if not rendered somewhat conspicuous to the sight of other insects, might do too much damage to the tribes which they keep in check, and endanger

the balance of Nature. Most of these therefore have the thorax and abdomen margined with a light colour, which contrasts strongly with that of their bodies, and in many cases gives timely warning of their approach.

The tropical genera gasteracantha and acrosoma are invested with large angular spines, sticking out of their bodies in every kind of fashion. Temptingly suspended in mid-air in the forest-glades, they would long since have been destroyed by the sharp-sighted birds, if Providence had not effectually protected them by this defensive armour, which prevents them being swallowed with impunity.

An amazing fecundity and a strong maternal instinct essentially contribute to shield the spider race from destruction. The arachnidæ are in all other respects extremely unamiable creatures, of a morose irascible temper, and utterly insensible to the charms of connubial affection; but their tenderness for their young brood, the only thing they love on earth, is truly exemplary, nor will the greatest personal danger ever induce them to forsake their cocoons. When a seizure of this precious burden is threatened, the theridion tumbles together with it to the ground and remains motionless; while the thorinsa covers it with its body, and when robbed of it wanders about disconsolate.

Antelme relates how he once put the maternal fondness of a spider to the test. Having robbed her of the little silken bag in which her infant progeny was contained, he observed how anxiously she ran about, evidently seeking her lost treasure. Her tormentor having restored the bag, she seized it hastily, and endeavoured to escape as fast as she could. But the cruel naturalist, not satisfied with this first experiment on her feelings, robbed her once more, when she again exhibited the same symptoms of despair. He now reached her small bullets of cotton and bread-crumbs, made to resemble her cocoon, but these were indignantly rejected; for the heart of a mother is not easily deceived, and the poor spider only regained her tranquillity when she was at length allowed to depart in peace with her recovered treasure.

Bonnet, an eminent Swiss naturalist of the last century, delivered up the little silken bag of the aranea saccata to that cruel insect the ant-lion, when the distressed mother, far from deserting her charge, made the most extraordinary efforts to

recover it,—persevering regardless of her own danger, and resolutely remaining on the spot, in spite of every effort to force her to leave it.

As the chief use of the spiders in the household of Nature consists in their checking the inordinate increase of the insect-tribes, they may naturally be expected to be most numerous where they are able to find the most abundant prey. Thus their headquarters are in the torrid zone, and here also, where so many beetles, flies, and moths attain a size unknown in the temperate regions, we find by a beautiful harmony of Nature the spiders growing to similar gigantic dimensions, and forming webs proportioned to the bulk of the victims which they are intended to ensnare. But their numbers are also very great in the temperate regions of the globe, and the morning dew frequently shows the hedges and meadows covered with their countless webs, brought out in silvery relief.

Extending in gradually diminishing numbers to the North, they ascend the slopes of high mountains, and even dive into the darkness of nightly caves, where, though deprived of sight, they manage to catch their prey in a manner which to us is totally incomprehensible.

Thus the *eyeless* stalita tænaria dwells in the Grotto of Adelsberg, where she lies in ambush for the yellow cave-beetle (*Leptodirus Hohenwartii*), which has likewise been doomed to pass its life in subterranean darkness. Even on the insect-teeming surface of the earth, the patient spiders are frequently obliged to wait a long time for a repast; here in this thinly-peopled cave the stalita must have brought patience to perfection. Her appearance on the snow-white stalactites, which she resembles in colour, and where she becomes visible only in a strong light, is remarkably striking. Like a vision she sweeps away in her ivory robe, accompanied by the lengthening shadow she throws back in her flight, so that a superstitious or fanciful observer might easily take her for the spirit of the place.

CHAPTER XXIV.

FISHES.

The Waters a Scene of constant War—Fecundity of Fishes necessary to maintain the Equilibrium—Migrations of the Salmon—Means of Defence and Attack—The Dragon Weever—The Acanthurus—The Catfish—The Sting-ray—Dental Apparatus of Fishes—Teeth of the Lamprey and Scari—The Sawfish—Electrical Fish—Fins—Air Bladders—Gills—Respiratory Apparatus of the Lamprey and Hag—of the Frogfish and Hassar—The Star Gazer—The Angler—The Rostrated Chætodon—The Senses of Fishes—Beautiful Construction of their Eye—Care of the Stickleback for its Young—Parental Solicitude of the Black Goby and of the Hassar.

In the wide ocean, under the tranquil surface of the lake, in the majestic river that pays the tribute of its waters to the sea, in the brook rushing down the valley—as far as the domains of the fishes extend, there is a constant war, a constant pursuit and flight, a constant alternation between victory and death.

A great proportion of the vertebrated animals of the dry land consists of gentle herbivora—almost the entire race of rodents: the stag, the ox, the horse, the sheep, the giraffe, the elephant, the rhinoceros, the hippopotamus, and many others, all live on vegetable food; but the vast majority of fishes, from the smallest to the largest, from the tiny stickleback to the shark, are perpetually intent on rapine and murder, and, except in the breeding season, the sole occupation of their life is to pursue a prey or to escape from a pursuer.

Amidst all these scenes of anarchy and destruction the superficial observer might almost be inclined to imagine that Moloch, and not a beneficent Deity, had established his throne in the ocean; but a deeper insight into the life of fishes soon proves to us that here, as everywhere else, apparent discord is but the means of promoting harmony.

In spite of their perpetual losses, the many thousand species of fishes that people the empire of the seas maintain themselves

against their enemies: the herring still rises in legions from the deeper waters, as soon as the coasts are warmed by the genial influence of the vernal sun; the salmon still wanders up the streams that witnessed the migrations of his forefathers in far-distant ages, and the cod never ceases to fulfil the expectations of the fisherman.

Under the protection of an Almighty Lawgiver the equilibrium of the inhabitants of the ocean is thus constantly preserved though constantly assailed; and though the scythe of death is indefatigably mowing throughout Neptune's domains, it is but to celebrate the eternal triumph of life.

In various ways Providence has found means to preserve the persecuted races of the fishes: particularly among those that annually congregate on sandbanks or on the coasts, or are exposed during their migrations to numberless attacks, a surprising fecundity makes up for exorbitant losses. Five hundred thousand eggs have been found in a single mackerel, a million and a half in a flounder, six millions in a sturgeon, ten millions in a cod, and twenty millions in a salmon. Thus myriads of eggs may be devoured by other fishes; seals, sea-birds, and man, the most rapacious of all carnivorous beings, may feed for months upon millions of the herring or the cod before they retire again to the depths of the ocean; and yet the species resists every storm, and continually reappears in undiminished numbers.

The wonderful instinct which forces the salmon, the sturgeon, and other fishes periodically to leave the sea, for the purpose of depositing their spawn upon the shallow beds of rivers, is another of the great agencies which Nature employs for the maintenance and wide dissemination of many of the finny tribes that would otherwise have been confined to narrow limits, or would long since have been extirpated by their enemies.

Generally inhabitants of the cold and temperate zones, these fishes find during the winter, in the deeper waters of the sea, the warmth and nourishment which the frozen streams no longer can afford them; but in spring and summer, when the rivers teem with numberless worms and insects, and their tepid waters afford the necessary warmth for the hatching of their eggs, they begin their wanderings stream-upwards, frequently ascending many hundreds of miles from the river's mouth in regular array; the largest individual, which is usually a female, taking the

lead, and the others following two-and-two, each pair being at the distance of from three to six feet from the preceding one. The numerous bands of salmon will thus force themselves against the most rapid streams, and even considerable cascades are unable to stop their progress; for placing their tail in their mouth, and letting it go suddenly, they raise themselves in the air to the height of from twelve to fifteen feet, or even more, and so clear the cataract that impedes their course; nor, if they fail in their first attempt, do they allow themselves to be discouraged, but continue their efforts till they have accomplished their task.

It is a remarkable circumstance that the salmon on his wanderings never tarries in the deep lakes any longer than is necessary to reach the rivers that flow through them. Who teaches him the way? Who tells him when entering the Lake of Zurich that at its farthest extremity he will find the narrow bed of the Linth, or that, after traversing the long and sinuous Lake of Lucerne, he will again reenter the rapid stream of the Reuss?

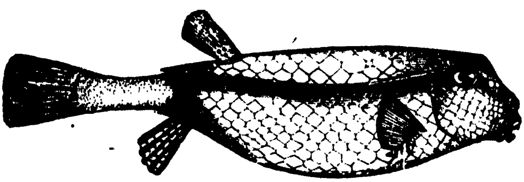
And how surprising is the memory which annually leads him back from the ocean to the spot in which he has been bred, though while tarrying in the sea he may have roved for miles along the coast! Deslandes, a French naturalist, attached a copper ring to the tails of twelve salmon, and shortly after restored them to liberty in the River Auzun, in Brittany. They soon disappeared, but in the following year five were caught again at the same spot; the year after, three; and three again in the third year. To explain these miracles of instinct is impossible—all we can do is to admire them!

The frequent return of the salmon to his old haunts, and the large size he often attains, prove that, in spite of the many dangers to which he is exposed during his migrations, he not seldom reaches a good old age. Salmon weighing forty, fifty, or even eighty-three pounds have found their way to the London market; and when we read of sturgeons twenty-five feet long, and of halibuts of three hundredweight, we cannot doubt that these colossal individuals had long outgrown their youth, and were in the enjoyment of a truly patriarchal longevity.

Not all the members of the finny tribes are endowed with the prodigious fecundity of the cod or the sturgeon, of the mackerel or the salmon; for where it is not so necessary, or where a too-

rapid increase might have destroyed the balance of marine existence, propagation has been providently reduced to narrower limits. Thus the gaudy filefish that swim like animated gems among the coral-gardens of the tropical seas, and are not only able to seek a ready refuge among the dense branches of the lithophytes, but whose skin is moreover covered everywhere with minute spines, are far less prolific than the migratory fishes; and the voracious rays and sharks, whose inordinate increase would have given them a dangerous supremacy in the maritime domains, bring forth but a few young at a time. As the length of the newly-hatched white shark—which at a later period is, in size and voracity, the most formidable of all the species—does not exceed a few inches, we also may be sure that numbers of these young monsters are swept away before they are entitled to rank among the tyrants of the deep.

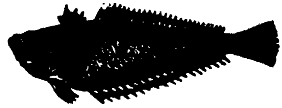
In their double quality of predaceous and persecuted animals, the fishes are well provided with those means of attack or defence that are absolutely necessary for their maintenance on a scene of perpetual warfare. Many of them trust to the wonderful velocity of their movements; while others, conscious of inferior agility, conceal themselves in the mud or among the rocks and sea-plants—either to escape pursuit, like the hare, or to pounce, like the falcon, upon their unsuspecting prey. In the ostracion and lepidosteus we see a solid cuirass of hexagonal scales, inclosing the animal in an almost impregnable citadel; while the tetrodons and diodons have the power of inflating their body at pleasure, and thus raising the long acute spines dispersed over their side and abdomen, in such a manner as to form a defence as excellent as that of the hedgehog or porcupine.



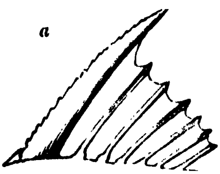
Ostracion. (Tortoise Fish.)

The little stickleback not only makes use of its dorsal spines as a means of defence, but as a formidable offensive weapon; for the males are exceedingly pugnacious, and in their pigmy broils use them with such fatal effect, that one occasionally rips up and kills the other.

The strong spines of the dragon-weever, a small silvery fish frequently occurring on our shores, are capable of inflicting such troublesome and painful wounds that they are the objects of the fisherman's dread; and the lancet-like moveable spines, not unlike the very large thorns of the rose-tree, with which the tropical surgeon-fishes (or Acanthuri) are armed on each side of the tail, inflict a most terrible gash on the hand of anyone so imprudent as to come within their reach.


Common Weever (Trachinus Draco).

Several of the siluridæ, or catfish, use the sharp spine of their dorsal fin (*a*), in a very peculiar manner, for the obtaining of their food. Getting beneath the fish they have selected for their meal, they suddenly rise and wound it repeatedly in the belly. Michaux several times observed this ingenious piece of strategy in the clear waters of the Ohio.



Dorsal fin of Catfish.

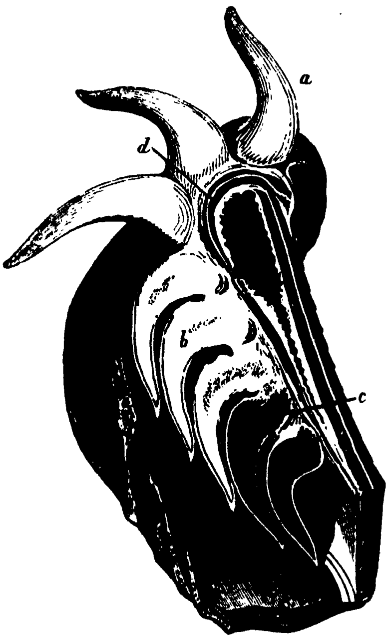
One of the most formidable of the numerous spine-armed fishes (of whom, not to tire the reader, I have mentioned but a few) is beyond all doubt the sting-ray. Its weapon is a long bony and rather flattened process, placed on the tail, of great hardness, and very sharp, the sides being armed with numerous barbs, like the head of an Indian spear. Whether the fish, at the time of inflicting a wound with this instrument, discharges some poisonous liquid, or whether the laceration of the wound indisposes it to heal kindly, is still a matter of doubt; but so much is certain, that the sting of these rays has often been attended with fatal consequences, and that the pain it causes is such as to deprive the sufferer of consciousness.

The fishes rely chiefly upon their dental apparatus for the capture of their prey, as they have neither feet nor hands to lay hold of it; and as the creatures they pursue through the waste of waters are generally of a slippery nature, we find their teeth, by their sharpness, position, and numbers, most admirably adapted for their seizure.

In many of the larger fishes these instruments of destruction are as formidable as those of the lions or tigers of the dry land. Thus the shark will at one grip cut a man in two, swallowing

one half, and leaving the other for a second morsel; and such is the power of the seawolf's jaws, that he will crunch a cutlass as if it was made of glass.

The teeth of the fishes are not, like those of the quadrupeds, consolidated with certain bones of the mouth, or implanted into the jaws, but, like the scales, prickles, and spines, are of merely cuticular origin. Hence they afford an amazing variety of form and position, being attached to any or to every part of the mouth, according to the necessities of the given species; hence also their numbers are often very large, and capable of constant renovation. Sometimes they are so minute as only to be perceptible by the rough or scabrous surface which the parts of the mouth to which they are attached present. If of larger size, they exhibit the appearance of a file or rasp, or they may have the shape of small cones or hooks thickly scattered over the mouth.

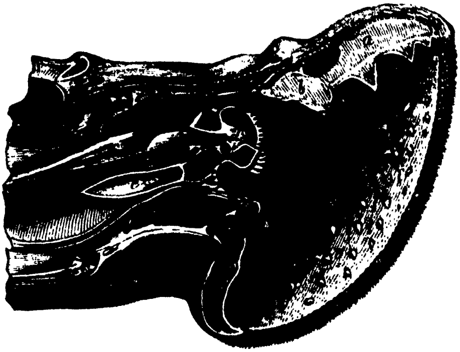


Teeth of Shark.
c divided tooth to show that it is hollow, *d* fibro-mucous layer, which by its growth brings the successive rows progressively into use.

In the sharks, they consist of several rows of broad and trenchant laminæ, the anterior row of which (*a*) stands up perpendicularly from the jaws, ready for use, while the succeeding layers (*b*) are recumbent, being covered over by a fold of the mucous lining of the mouth. These teeth, like those of the rays, are perpetually renovated, new and sharp rows behind being constantly ready to replace the old and worn ones in front, as soon as the latter fall out or become useless.

In the lamprey, which does not sever its victims by a powerful bite, but sucks their blood like a leech, the teeth are very differently though not less admirably arranged; for here they are

composed of horny plates or tubercles of different forms, which are disposed with great regularity over the whole surface of the sucker-shaped mouth, so as evidently to secure a deadly hold of



Dental apparatus of the Lamprey.
b fang fixed to the roof.

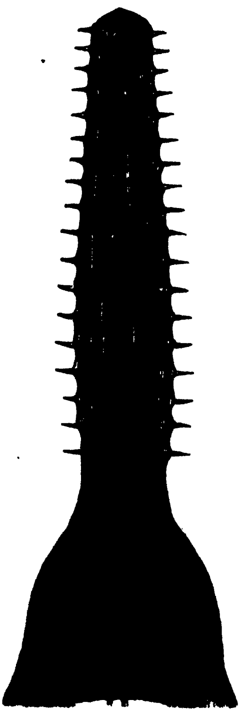
any victim seized upon. The tongue (*d*), which is very moveable, and capable of being retracted and protruded by means of strong muscles, is likewise armed with serrated teeth, with which, as with a rasp, the lamprey tears through the flesh of its prey.

In the scari, which have to feed upon the numerous lithophytes that clothe the rocks at the bottom of the ocean, the dental apparatus given to protect their jaws from injury is very remarkable. These fishes have their jaws (*a*, *b*), which resemble the beak of a parrot, covered externally with a kind of pavement of teeth, answering the same purpose as the horny investment of the mandibles of the bird, and succeeding each other, from the rear to the front, in such a manner that the bases of the newest form a cutting edge. Thus armed, the parrotfish browses without difficulty on the

Beak of Parrotfish. (Scarus muricatus.)

newest layers of the stony corals, digesting the animal matter therein contained, and setting free the carbonate of lime in a chalky state.

The maxillary teeth of the sawfish, which is an active and predatory shark, are notwithstanding its habits extremely small, simple, obtuse, and wholly inadequate to destroy and secure the prey requisite for its subsistence. But this seemingly imperfect armature of the mouth is compensated by the development from the anterior part of the head of a horizontally flattened process, equalling one-third of the entire fish in length, and provided with strong teeth, deeply lodged in sockets excavated on each of its lateral margins. With this formidable weapon, which is quite unique among the whole finny race, the sawfish does not fear to engage even the monstrous whale in deadly combat. The whale, whose only defence is his tail, endeavours to strike his enemy with it; and a single blow would prove mortal. But the sawfish with astonishing agility shuns the tremendous stroke, bounds into the air, and returns upon his huge adversary, plunging the rugged weapon with which he is furnished into his back, or ripping up his skin with a tremendous gash. The whale is still more irritated by the wound, which becomes fatal only when it penetrates the fat; and thus, pursuing and pursued, striking and stabbing, the engagement only ends with the death of one of the unwieldy combatants.

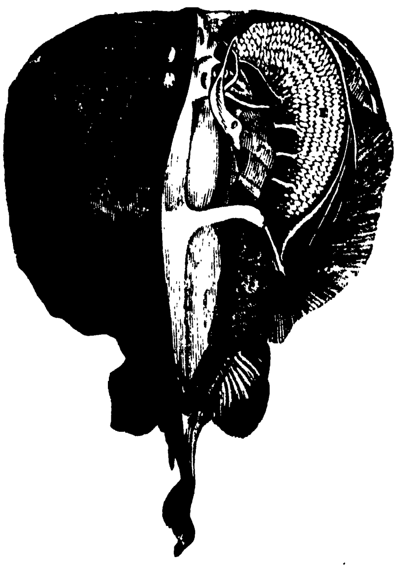


Rostrum of Sawfish (Pristis antiquorum), showing the marginal teeth.

While most fishes rely only upon their teeth, their physical strength, or their rapidity for attack or defence, some have been gifted with the wonderful power of stunning their enemies or their victims by electrical discharge. In no other class of animals do we find creatures similarly armed; and it is indeed one of the inscrutable mysteries of creation, that the powerful weapon of a galvanic battery, which man has learned to wield only after attaining

a high degree of civilisation, should have been bestowed, most likely long before man appeared upon the stage of life, upon a few members of the finny race, and to these alone of all created beings.

The electrical organs vary considerably in situation and form in the different fishes to which they have been given. Thus in the electric eel (*Gymnotus electricus*), which inhabits the large rivers of South America, they run along the tail, while in the torpedo of the Mediterranean they are situated on each side of the anterior part of the body. In this formidable ray they consist of a multitude of small prismatic columns (E), invested with strong fascial coverings. These prisms lie close together, parallel with one another, and perpendicularly between the dorsal and ventral surfaces of the fish, so that their extremities are separated from these surfaces only by their fascial and common integuments. When these are removed the columns present something of the appearance of a honeycomb. Each column is again divided into numerous distinct compartments, by delicate membranous partitions placed horizontally at very short distances from each other (150 to an inch), and covered with a fine network of arteries, veins, and nerves. The interstices between them are filled with a gelatinous mass.



Muscles and Electric Batteries of the Torpedo
(Owen's Lectures.)

In the electric eel a similar subdivision takes place by means of longitudinal plates and transverse membranes, which however are placed much more closely together than in the torpedo, as 240 of them have been counted in an inch. By this structure an immense discharging surface is obtained; for in a torpedo of ordinary size, where the electrical organ is seven or eight inches

long, it is equal to fifty-eight square feet, and in an electrical eel four feet in length, it is at least 123 square feet in extent.

In both these fishes the electricity generated by the action of these wonderful batteries, besides its benumbing and stunning effects on living animals, renders the needle magnetic, decomposes chemical compounds, emits the spark, and in short exercises all the other known powers of the ordinary electricity developed in inorganic matter, or by the artificial apparatus of the laboratory.

Electrical fishes exert their peculiar power only occasionally and at irregular intervals, and chiefly when excited by the approach of some animal, or by the irritation of their surface by some foreign body. The discharge, both with regard to time and intensity, seems to be dependent on an exertion of the will. Sometimes the torpedo buries itself in the sand left dry at ebb-tide, and it has occasionally happened, according to some naturalists, that persons walking across the sand and treading upon the spot beneath which the electrical fish lay concealed, have received a discharge strong enough to throw them down.

The effects produced by the gymnotus are more severe, for those eels are able when in full vigour to kill the largest animals, when they suddenly unload their electrical organs in a favourable direction. All other fishes, aware of their power, fly at the sight of the formidable gymnotus. They stun even the angler on the high river-bank, the moist line serving as a conductor for the electric fluid.

The capture of these eels affords a highly entertaining and animated scene. Mules and horses are driven by the Indians into the streams or marshes which they infest, until the unwonted noise and splashing of the waters rouse the fishes to an attack. Gliding along they creep under the belly of the horses, many of whom die from the shock of their strokes; while others, with head erect and dilated nostrils, endeavour to flee from the electric storm which they have aroused. But the Indians, armed with long poles and uttering wild cries, drive them back again into the pool. Gradually the unequal contest subsides. Like spent thunderclouds the exhausted fishes disperse, for they require a long rest and plentiful food to repair the loss of their galvanic powers. Their shocks grow weaker and weaker. Terrified by the noise of the horses, they timidly approach the banks, when,

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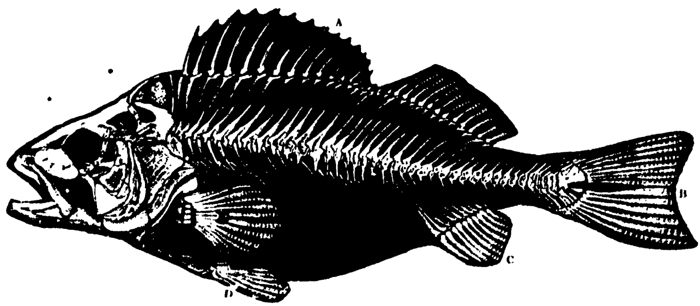
wounded with harpoons, they are dragged on shore with dry and nonconducting pieces of wood, and thus the strange combat ends.

In no class of the animal kingdom do we find such diversity of form as in that of fishes. Some amongst them are perfectly spherical, others flat or circular; but generally they are of an elongated oval shape, a figure which enables them with greater celerity and ease than any other to pass through the water. Their viscera are packed in a small compass in a cavity brought forwards close to the head, and whilst the consequent suppression of the neck gives the advantage of a more fixed and resisting connection of the head to the trunk, a greater proportion of the body behind is left free for the development and allocation of the powerful muscular masses which are to move the gradually-tapering tail, whose lateral rapidly-alternating strokes are its chief means of progression through the water. We wisely endeavour to imitate this peculiar shape in the construction of



our ships, yet the rapidity of our fastest clippers is nothing to the velocity of animals that have been specially formed for natation by an Allwise Hand. The energetic action of the tail is assisted by the dorsal (A), caudal (B), and anal (C) fins, which serve by their vertical position to increase the rowing surface, and thus add considerably to the rapidity of motion; while the pectoral (D) and ventral (E) fins, which correspond to the fore and hind limbs of the higher vertebrates, are of the greatest importance in directing the movements of the animal. With the help of these highly flexible organs, fishes can turn about

in the water as they please; and it is curious to observe how, alternately expanding or contracting one fin or the other, they gracefully plough the liquid element in every direction.

It is no less wonderful how perfectly the size and texture of the fins correspond with the habits and necessities of the different species of fishes. Those which traverse vast spaces of the ocean are furnished with large and strong fins, to enable them to struggle against swelling waves and rapid currents; while these organs are soft in the species which confine themselves to more tranquil waters, or habitually reside in greater depths untroubled by the winds which agitate the surface.

In the snake-formed fishes, where the whole vertebral column is extremely flexible, and consequently renders the assistance of the fins less necessary, these ancillary organs are reduced in size and number; while in the exocœti or flying-fishes, the pectoral fins are of so great a length as to be able to carry them like wings a great distance through the air. Thus they frequently escape into another element from the pursuit of the arrowy bonito or the darting dolphin; and though gulls and frigate-birds may seize them now and then during their aërial flight, yet there can be no doubt that they have good reason to be thankful for the gift of their pinion-fins, without which they never could have maintained themselves on the high seas along with their predaceous pursuers.

To enable the fish to rise and sink in the water without continued muscular effort, they have been provided with the air-bladder. This hydrostatic apparatus is of various shapes, but always of sufficient dimensions to contain, when it is distended, as many cubic inches of air as will render the fish specifically lighter than water; and as the specific gravities of air and water are to each other nearly as 1·815, a small volume is sufficient to render the lesser fishes lighter than the medium they inhabit. When they contract this remarkable gas-reservoir, or press out the included air by means of the abdominal muscles, the bulk of the body is diminished, its weight in proportion to the water is increased, and the fish swims easily at a greater depth. The contrary takes place on relaxing the tension of the abdominal muscles, and thus we see fishes rise and fall in their denser element by the application of the same physical law which is made use of by our aëronauts

to scale the heavens or to descend again upon the earth. The position of the air-bladder immediately under the spine and above the centre of gravity, causes the fish to rise without the danger of turning over on its back. Thus the air-bladder is a highly important auxiliary organ of locomotion, and affords an illustration of one of the many evidences of design in the primary formation of aquatic animals.

In the flying-fishes, whose peculiar habits rendered a greater lightness of body extremely desirable, it is of enormous size, so that when distended it fills almost the entire abdominal cavity; while in those fishes which are destined to live at the bottom of the sea, or habitually to conceal themselves in the mud, it is either very small or entirely wanting—for economical Nature constantly regulates her gifts according to the wants of her creatures.

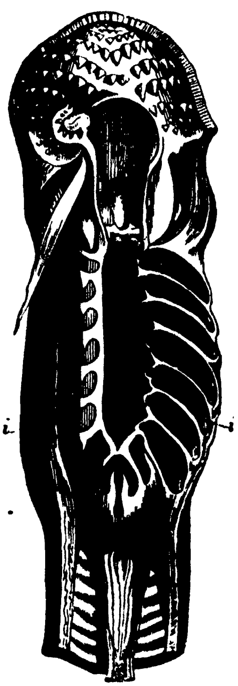
The gills of the fishes are as beautifully constructed for aquatic respiration as the lungs of the terrestrial vertebrate animals for breathing in the air. In most fishes, comprising all the bony fishes and the sturgeons, among those which have a cartilaginous skeleton, we find, in the interior of the mouth at each side, five apertures separated from each other by four crooked parallel and unequal bones, and leading to a cavity which is closed on the outside by an operculum or cover. In this cavity, and to the external convex surface of each of the four bones or branchial arches, is attached a double series of flat elongated cartilaginous laminæ, tapering gradually towards their extremities; the whole forming a crescent-shaped framework toothed like a comb, over which is spread the delicately-fringed and highly vascular membrane that constitutes the respiratory surface. Over this the water taken in at the mouth is made to pass as it issues through the opercular cavities, and in this way the branchiæ, being perpetually bathed with aërated water, perform the same office as the lungs of an air-breathing animal.

This transmission of the water in one direction is in more than one respect a most wise provision of Nature, for if the fishes were obliged to receive and reject the water by the same aperture (as we do the air), each respiration would evidently drive them backwards, and consequently retard their movements. It is also evident that the delicate fringes of the gills must have been liable to perpetual derangement, if the

water had been made to pass through them in two opposite directions.

In the sharks and rays we find a different arrangement of the gills, as here the branchial arches are not freely suspended in the branchial chamber, but stretching across its cavity divide it like so many bulkheads into five distinct compartments, whose walls are tapestried with the innumerable folds of the branchial membrane. The water entering the mouth does not escape through an opercular opening, but through five distinct orifices situated on each side of the body.

In the lamprey and hag the branchial apparatus on each side is similarly divided into seven compartments; but these fishes, from the peculiarities of their habits, require another modification in the construction of the organs of respiration, seeing that while they rest fixed by their suctorial mouths to the surfaces of stones or other foreign bodies, or while they are compelled to remain with their heads deeply plunged into the flesh of the prey upon which they live, the admission of water into the mouth and its subsequent expulsion through the gill-openings (*i*) would in their case be impracticable. Here, therefore, a framework of cartilaginous pieces forms a kind of elastic thorax around the regions of the body where the branchiæ are situated, and by its alternate movements of contraction and dilatation perpetually sucks in the water and again expels it through the external openings.



Respiratory Apparatus of the Lamprey.

d cavity communicating with the respiratory sacculi of both sides.

In the myxine or hag these orifices are moreover situated very far back in comparison with the usual situation of the gill-openings, so that the creature is able to respire while deeply plunging into the soft parts of its unfortunate victim. Thus even in this meanest and lowest of all vertebrate animals we find a remarkable adaptation of its construction to its wants, and the proof that it has been as well taken care of by the Creator as the highest members of its class.

Though the whole breathing apparatus of a fish is comprised in a small compass, its surface if fully extended would occupy a very considerable space—that of the common skate, for instance, being equal to the whole external surface of the human body. This single fact may convince us of the numberless ramifications and convolutions of the gills, and how wonderfully Nature has contrived to multiply within very narrow limits the points of contact between the minute bloodvessels and the aërated water that flows along their sides. It may seem strange that when fishes are taken out of their native element they generally die almost immediately from want of air: such, however, is the case, for the gills being no longer floated out collapse, and thus, by preventing the passage of blood through the delicate branchial arteries, put a stop to the circulation as completely as strangulation could do.

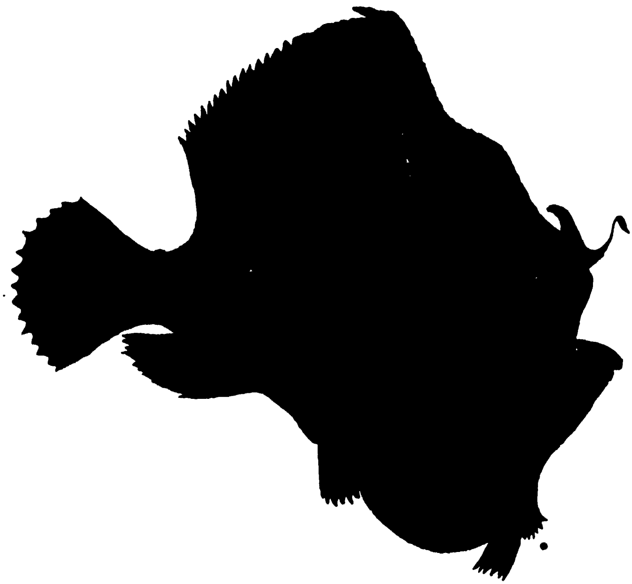
In some genera, however, a provision is made to permit of a more lengthened existence out of the water, where the habits of the fish render such an arrangement necessary. In the whole tribe of eels, for example, the external fissure is removed very far back and reduced to a very small vertical slit, converting the cavity in which the branchiæ are lodged into an elongated chamber, in which a sufficient quantity of water can be retained to allow respiration to continue for a considerable time in the air. Thus the eels are able to travel during the night over the moist meadows, in search of frogs or other suitable food, or to change their situation.

In several tropical fishes we find the gills communicating with a cellular labyrinth containing water, which serves to keep them moist. It is owing to such an apparatus, without which they could not possibly exist during the long-continued droughts of the arid season, that the climbing perches of India (*Anabas*), the hassar of Guiana, and the frogfishes of Ceylon are able to wander overland in search of their natural element, when the ponds or rivers in which they sojourned are dried up. An admirable instinct teaches them to shape their course towards the nearest pool, and the peculiar formation of their fins assists them in their migrations.

Thus in the frogfish the bones of the carpus form arms that support the pectoral fins, which thus perform the office of feet; and the hassar, projecting itself forwards on its bony pectoral

fins by the elastic spring of the tail, exerted sidewise, proceeds in this manner nearly as fast as a man will leisurely walk. The strong scuta or bands which envelope the body, in the manner of the plates under the belly of serpents, also greatly facilitate its march, as they can be raised or depressed by a voluntary power.

When the pools and rivers are everywhere dried up, these migratory fishes bury themselves in the mud as a last resource,



Frogfish.

and fall into a kind of asphyxia, or lethargy, till the rainy season recals them again to life.

In general the manner in which the fishes procure their food is extremely simple, and requires but a very small amount of intelligence or art: they see their prey, rush furiously upon it, and devour it with greedy haste.

Some species, however, have recourse to stratagem for this purpose. Thus the stargazer (*Uranoscopus scaber*), hidden in the mud, exposes only the top of the head, and waving the beards with which his lips are furnished in various directions, decoys the smaller fishes and marine insects that mistake these organs for worms.

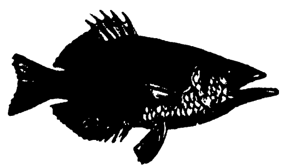
The position of the eye, placed on the upper surface of the

nearly cubical head, and directed towards the heaven, is no less admirably adapted for this 'artful dodge' than the vertically-cleft mouth which enables the cunning fish to swallow his prey without deranging his position.

The angler or sea-devil (*Lophius piscatorius*), a slow swimmer, who would very often be obliged to fast if he had merely the strength of his fins to rely upon, uses a similar deceit. Lying as it were in ambush at the bottom of the sea, he stirs up the mud and sand, and, hidden by the obscurity thus produced, attracts many a prize by leisurely moving to and fro the two slender and elongated appendages on his head—the first of which, the better to deceive, is broad and flattened at the end, inviting pursuit by the shining silvery appearance of the dilated part.

Angler (Lophius piscatorius).

But of all the fishes that prefer artifice to violence for the obtaining of their food, there are none to equal the chætodons and archer-fishes of the Eastern seas. When the rostrated chætodon, a native of the fresh-waters of India, sees a fly alighting on any of the plants which overhang the shallow stream, he approaches with the utmost caution, coming as perpendicularly as possible under the object of his meditated attack; then placing himself in an oblique direction, with the mouth and eyes near the surface, he remains a moment immoveable, leisurely taking his aim, like a firstrate marksman. His eyes steadfastly fixed on the insect, he darts at it a drop of water from his long tubular snout, expressly formed for his feats of archery, but without protruding his mouth above the surface, from which only the drop seems to rise, but with such effect that, though the distance may be four or five or six feet, it seldom fails to bring down its prey into the water. As their name indicates, the archer-fishes are equally expert. The Javanese, who take a delight in seeing them show their skill, keep them as a kind of household animals, and frequently amuse themselves by bringing flies or ants within a convenient distance of their almost unerring aim.



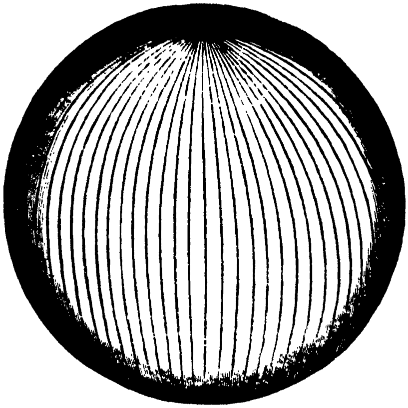
Archer-fish.
(Toxotes jaculator)

As fishes breathe by the medium of water, and thus profit only by the small quantity of oxygen contained in the air it has absorbed, we cannot wonder that the circulation of their blood is extremely slow. Their heart, in comparison with ours, is in fact but half a one, as it merely serves to force the venous blood into the gills, whence the aërated blood does not flow back to the heart as with us, to be rapidly and strongly propelled through the body, but proceeds immediately to the arteries, which are merely aided by the contraction of the surrounding muscular fibres. As respiration is a species of combustion, it is evident that only a cold blood could be formed under such circumstances, and, as may be expected, the blunt sensations of the fishes harmonize with the torpid nature of the fluid from which their organs derive their sustenance. Fishes, in fact, of all the vertebrates, give the least evidence of sensibility. Having no elastic air at their disposal, they are dumb or nearly so, and all the sentiments which voice awakens are unknown to them.

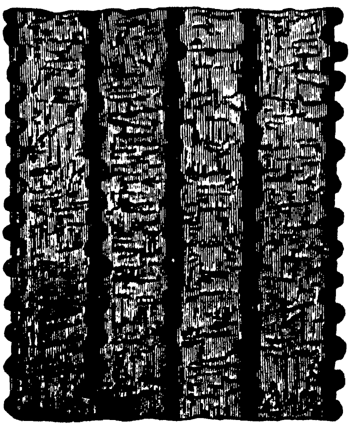
Being only able to support themselves by pursuing a prey which itself swims more or less rapidly, and having no means of seizing it but by swallowing, a delicate perception of savours would have been useless if Nature had bestowed it; but their tongue, almost motionless, often entirely bony, and only furnished with a few slender nerves, shows us that this organ is as obtuse as its little use would lead us to imagine it to be.

Their sense of smell is equally imperfect, and their touch—almost annihilated at the surface of their body by the scales which clothe them, and in their limbs by the want of flexibility in their rays—is confined to the ends of their lips, and even these in some are osseous and insensible. Their ear, which is entirely enclosed in the cranium, can hardly suffice to distinguish the most striking sounds. Their eyes finally are motionless as it were, and void of all that fire and animation which gives so much expression to the physiognomy of the higher animals; but the structure of these organs is admirably adapted to the element in which they live, by the spherical form and great size and hardness of the crystalline lens, which by concentrating the rays of light enables them to see with distinctness even through so dense a medium as that which surrounds them. This is, in truth, one of those wonderful provisions made for the particular necessities of every living thing.

On a closer examination, the lens is found to be composed of several thousands of regular transparent laminæ or spherical coats of uniform thickness: each of these laminæ consists of about 2,500 fibres, extending from pole to pole of the sphere, and being consequently widest at the equator. The mode in which these fibres are fastened together, so as to resist separation and form a continuous spherical surface, is very curious; the contiguous fibres being united by means of teeth, about 12,000 in each fibre, exactly like those of rackwork—the projecting teeth of one fibre entering into the hollows between the teeth of the adjacent one. As the fibres gradually diminish in size towards the centre of the lens and the teeth in the same proportion, so that the number of fibres or teeth in any spherical coat or lamina is the same from whatever part of the lens it is detached, it is not difficult to calculate their number. Thus the lens of a small cod, four-tenths of an inch in diameter, contains no less than five millions of fibres and sixty-two thousand five hundred millions of teeth! 'A transparent lens exhibiting such a mechanism,' says Sir David Brewster, who was the first to investigate its wonders, 'may well excite our astonishment and admiration!'



Direction of Fibres in Crystalline Lens of Cod (magnified).



Teeth of Fibres in Crystalline Lens of Cod (highly magnified).

As the eyes of the fishes are perpetually bathed by the water in which they live, we cannot wonder at the lachrymal apparatus

being totally wanting in their whole race; and as they are neither exposed to extreme variations of light, nor to the contact of dust, they generally also require no eyelid for their protection. In the common eel however, which bores cavities in the sand and mud at the bottom of the water, the eye is supplied with a hard and transparent membrane, which it can draw over the pupil at pleasure, thus effectually guarding these organs from injury. The eyeball of the herring is also defended by two vertical and transparent folds of the skin; and it is worthy of observation that where these folds decussate one another at their inferior extremities, the anterior one overlaps the posterior—so slight an impediment to progressive motion as the contrary position would have occasioned, having thus been foreseen and avoided.

As the external senses of fishes give them but few lively and distinct impressions, their pleasures are little varied; but, on the other hand, the painful impressions they receive from the external world are likewise circumscribed within narrower limits than those which bound the sensations of the birds and quadrupeds. Though often subject to the terrors of flight, they in their turn enjoy the excitement of pursuit; and a life of liberty makes them amends for the violent end to which they are generally doomed. Many a domestic animal or captive bird would willingly exchange its hard lot for the free life of the fish, who from the greater simplicity of his structure, his want of higher sensibilities, his excellent digestion, and the more equal temperature of the element in which he lives, remains free from many of the diseases which torment the higher animals.

The affections of fishes are cold as themselves; but, though the vast majority evince no sign of parental affection, and abandon their offspring to the mercy of the sea and their predatory companions, from the instant that the ova are shed, yet some at least show glimpses of that self-denying instinctive love for their young which often beams forth in so touching a manner among the birds or quadrupeds.

Thus, to preserve his eggs from the voracity of his brothers, the male stickleback collects the delicate fronds of water-plants or bits of grass that have been blown into the river, and forms them into a nest, the entrance of which he guards with the most sedulous care—repelling with tooth and prickles all other sticklebacks that approach the nest. If the enemy is too power-

ful, he has recourse to artifice—darts forth, seems actively engaged in the pursuit of an imaginary prey, and often succeeds in diverting the aggressor's attention from his nest.

The black goby, an inhabitant of the Mediterranean, likewise deposits its spawn in burrows dug among the roots of the sea-grass, and, watching over the entrance of the house, opposes sharp rows of teeth to every intruder; and the hassar, which I have already had occasion to mention for his extraordinary land-excursions, is no less remarkable for his habit of constructing nests, which are quite as well-formed as those of the stickleback, and are made of grass blades, straws, and leaves. These nests are very plentiful in the little muddy streamlets that intersect the sugar-marshes of Guiana, so that the habits of the fish can be easily watched. The parent-fish is very jealous of the eggs, and waits near them until they are hatched, and the young family committed to the water. The parental solicitude of the hassar is shamefully misused by man for his destruction: a small basket is held before the entrance, then the nest is gently struck with a stick; and furious, with extended fins, whose sharp points are able to inflict a painful wound, the poor hassar darts into the fatal basket.

CHAPTER XXV.

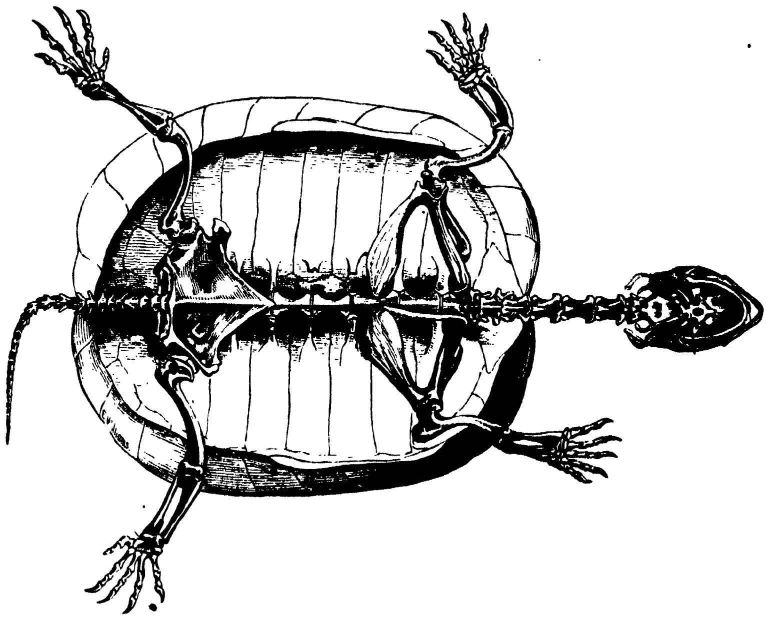
REPTILES.

Defences of the Chelonians, Lizards, Frogs, and Toads—Locomotion of Serpents—Legs of the Tortoise and Turtles—The Gecko's Foot—The Chameleon—The Viper's Fang—How Serpents swallow their Food—Tongue of the Chameleon and of the Crocodile—Vertebral Teeth of the Deirodon—Maternal Affection of the Cayman — Hybernation — Usefulness of Reptiles—Their Enemies and their Fecundity.

Unsocial, indolent, obtuse, the friends of darkness and solitude, as if ashamed of exposing their hideousness to the broad light of day, the Reptiles seem to be fit objects both of abhorrence and pity; and yet their structure is as perfect and harmonious in its way as that of the most highly-gifted among the birds and quadrupeds, and all their wants have been as carefully provided for.

Who, on seeing a tortoise slowly creeping along, would not suppose that so slothful an animal must, necessarily, succumb to the attacks of enemies infinitely its superiors in swiftness, in cunning, or in strength? And yet it has, in most cases, but little to fear from their violence or speed, for its spine, ribs, and breastbone are wonderfully developed and soldered together, so as to enclose the whole animal in a solid panoply of bone. This harness, as trustworthy as any in which the knights of old encased their limbs when about to plunge into the tumult of battle, is covered by the skin, which in its turn is plated with large scales, while all the muscles and viscera are contained in the inner cavity. Only the head, feet, and tail protrude through openings between the dorsal shield or *carapace* and the ventral cuirass or *plastrum*, but can at the creature's will be withdrawn entirely under the former. Thus, at the approach of danger, the tortoise need only shrink under the cover of its im-

penetrable bulwark to resist every attack by tooth or nail. The ventral part is less strongly plated, but most of the creature's enemies find it no easy task to turn it on its back, and thus to assail the fortress on its weakest side. As several species attain



Internal surface of Carapace of Tortoise.

a considerable weight, their mere bulk constitutes a good defence; and if it should be imagined that this protection could, after all, only avail for a short time, as in all probability the want of air must soon force the animal to stretch its head out of its hiding-place, yet this emergency has also been well provided for, as, having a cold blood, the tortoise can remain a long time without breathing—long enough, at least, to tire the patience of the most obstinate foe.

The turtles and river and marsh tortoises are not able, like their brethren of the dry land, to withdraw entirely under cover, but, as they are excellent swimmers, they stand less in need of this passive defence; besides, many of them are so strong and of so ferocious a disposition that, instead of fearing others, they are themselves objects of fear to most of the creatures that come within

their reach. Thus the loggerhead turtle roams like a famished tiger through the tropical ocean, and the river-tortoises are the terror of the fishes or even of the water-birds, whom they frequently surprise by suddenly darting their long necks at them, when they incautiously fly too near the surface of the treacherous stream. Though deprived of teeth, the turtles and tortoises are able to inflict a severe bite with their horny jaws, which fit one over the other like a pair of shears, and whose working surface is trenchant in the carnivorous species, but variously sculptured and adapted for both cutting and bruising in the vegetable-feeders.

Like the turtles and tortoises, the lizard tribes are spread far and wide over the sea and the land; and one genus—which, though harmless and inoffensive, bears the formidable name of dragon—is furnished with large expansile cutaneous processes, which enable it, like the flying-squirrel, to vault through the air, and spring from branch to branch among the lofty trees in which it resides. In this order also those that frequent the rivers or lagunes, such as the terrible crocodiles or the water-lizards of the Indian Archipelago, are slow and awkward when they creep on land, swift and alert in their own element; but the land-lizards, unlike the tortoises, are almost all distinguished by the swiftness of their motions, so that they can, if pursued, disappear with the rapidity of lightning in the crevice of a rock or a hole in the ground—and thus they make up by their agility for the want of a protecting harness.

The frogs and toads, though naked, and without claws or sharp teeth to offer an active resistance to hostile assault, are still sufficiently protected against a number of enemies.

Thus the strong muscular legs of the edible frog, who loves to warm his green livery on the sunny banks of his pond, render him as good services as he could possibly expect from the best suit of armour. There he will sit motionless for hours together, enjoying his refreshing air-bath, and imbibing heat and light at every pore; but as soon as his sharp ear detects the approach of man or beast, one single bound sends him plump into the water, and a few energetic strokes propel him far out of reach. Such is his muscular power that, with one leap, he can jump twenty times his height, or vault over a space fifty times his length. What would have become of him if this

wonderful elasticity of limb did not assist him in the hour of need?

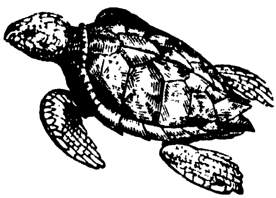
The toad has no agility to depend upon; but by day he perfectly understands the art of concealment under stones or mosses, or in the roots of trees; and the acrimonious fluid which he suddenly discharges when disturbed, or which, on irritation, exudes from his skin, may also serve to keep off many an enemy.

The snakes seem, at first sight, more defenceless than all the other reptiles, as they are altogether deprived of feet; and yet we see them glide along with great celerity, and apparently without an effort. Thus it is evident that a most excellent locomotive apparatus must lie concealed within their cylindrical and naked body; and a closer inspection teaches us that, by an admirable mechanism, their ribs are made to perform the office of legs. For while we only possess twelve pairs of these bones, joined together in front by means of the breastbone and cartilaginous processes, and serving merely to assist respiration, the ribs of serpents are exceedingly numerous, varying, according to the proportions of the species, from fifty-one pairs to three hundred and twenty. There is no vestige of a breastbone, so that each rib is capable of individual motion; and this facility of action is still further increased by each pair of ribs being moveably articulated, by means of two slight concave surfaces, with the corresponding vertebræ, forming a kind of double ball and socket-joint. Numerous strong muscles attach these long levers to the scuta or scales of the skin, while others run from scale to scale and from rib to rib; and thus we can easily comprehend how, with such a complicated system of pulleys and points of attachment, the reptile—bringing up the tail towards the head by bending the body into one or more curves, and then again resting upon the tail and extending the body—is able to shoot rapidly along, not only upon smooth ground or over the rough bark of trees, but even from branch to branch; as the smallest hold suffices for its stretching-out its body at a foot's length into the air, and thus reaching another sallying-point for further progress. Thus, also, the serpent does not feel the want of legs, which would indeed have been a great source of inconvenience while creeping through the dense bushes or tangled roots, or the masses of dead leaves that form its favourite haunts; and

thus, finally, the wisdom of its Divine Author shows itself in every movement of a creature we are accustomed to despise and loathe!

In those reptiles which possess limbs, we find these organs harmonising in every respect with their mode of life. In the land-tortoises the feet are mere awkward stumps; but these short and seemingly distorted members, terminating in obtuse claws, answer every useful purpose, while long and fleet limbs would not only have been superfluous to creatures who find in abundance the vegetable food they require, or who possess a sufficient defence against their enemies in the impenetrable harness which Providence has given them, but would, moreover, have been at variance with the remaining structure of the animal, as they could not possibly have been withdrawn under the protecting cover of the carapace.

In the turtles the feet, in perfect harmony with a different mode of life, are flattened out into the shape of fins or oars; and as in moving the principal efforts fall to the share of the forefeet, these are much longer and far more developed than the hinder extremities, whose action consists less in propelling than in steering. They are also assisted in swimming by a longer tail, which serves them as a rudder.



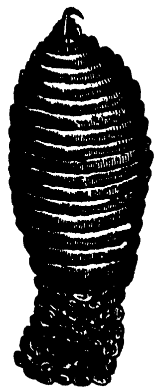
Loggerhead Turtle.

In the emydæ, or marsh-tortoises, which form as it were the connecting link between the land and river-tortoises, the toes are moveable, and furnished with long nails, so that these animals are well-fitted for moving on land, while at the same time their webbed feet are equally well adapted for swimming.

According to the more or less aquatic habits of the various species, the feet are more or less webbed; for in those that habitually remain on the banks of the lagunes, the connecting membrane is confined to the base of the toes, while in those which rarely frequent the shore it sometimes reaches to the extremity of the claws; and thus the inspection of the feet of a marsh-tortoise gives us at once a full insight into its habits.

Among the lizards the Geckoes are distinguished by the

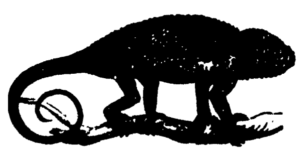
facility with which they climb up the vertical plane of walls, and walk in an inverted position on the ceilings of rooms. For this wonderful faculty, which, to all appearance, sets the laws of gravitation at defiance, they are indebted to an admirable pneumatic apparatus, which they employ in a manner similar to that of the house-fly. The under-surface of each of the five toes, which, with the exception of the thumb, terminate in a sharp claw, is furnished both in the fore and hind-feet with as many as sixteen transverse folds or plicæ, which open into as many cavities or sacks. The contraction of the muscles acting upon these plicæ and sacks erects the former, and dilates the cavities of the latter; the serrated edges being at the same time accurately applied to any smooth surface, a vacuum is produced, and by this structure the animal is enabled to perform its wonderful equilibristic feats without fatigue or any extraordinary effort.



Under-surface of Gecko's Toe (magnified).

The graceful anolis, which are peculiar to America, are similarly provided with suckers and long claws for the purpose of climbing, and moreover their strong muscular hind-legs enable them to leap with singular agility.

The chameleon is as perfectly fitted for maintaining itself with perfect ease and safety on the agitated branches of trees as the gecko for climbing on surfaces at every possible angle of inclination; for its short, strong, and muscular limbs are so constructed that two thumbs opposite to three fingers on the anterior extremity, and three thumbs opposite to two fingers on the posterior, form as it were a kind of pincers or hand, admirably suited for a holdfast. This strange animal possesses further a strong flexible and prehensile tail such as has been given to no other reptile, and which of course renders it material assistance in the maintenance of its arboreal station.



Chameleon.
(Chameleo Africanus.)

The skinks, a family of lizard-like reptiles in which there appears to be a gradual transition from the form of the lizards to that of the serpents, have but very short legs;

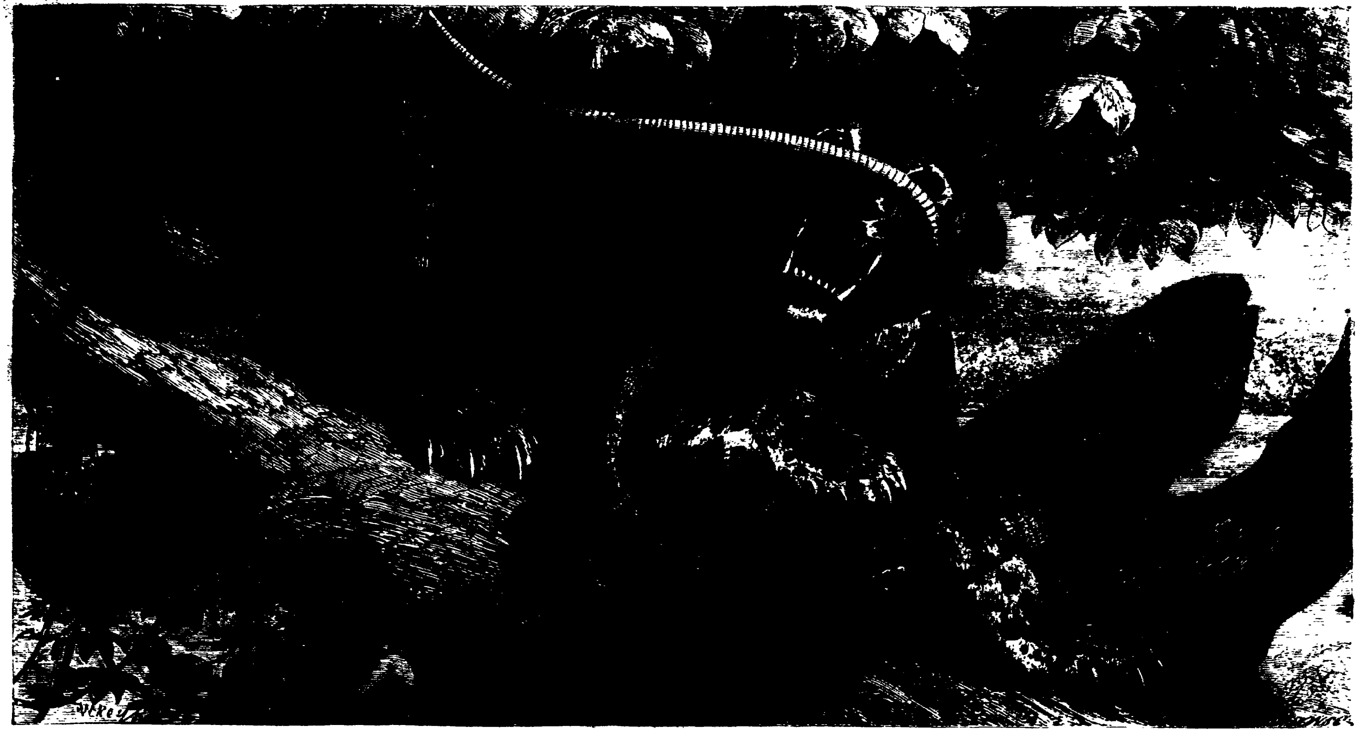
are well formed for burrowing, and, with the additional assistance of their flat wedgelike snout, enable them at the approach of an enemy to disappear under the sand almost as quickly as the mole burrows in the ground, or the seal dives under the water.

During the summer months, the tree-frog lives chiefly on the upper parts of trees, where it wanders among the foliage in quest of insects, which it catches with extreme celerity, either stealing softly towards its prey, or springing upon it with a sudden leap. For this arboreal life it is well fitted by the peculiar formation of its toes, all of which are terminated by round, flat and dilated tips, whose under-surface being soft and glutinous, allows it to climb with perfect security and ease; it can also adhere to any substance by its abdomen (which is covered with small glandular granules), by merely pressing itself against it. It is often seen suspending itself by its feet to the under parts of the leaves to enjoy their shade, while its green colour harmonising with that of the foliage masks its presence from its prey, and enables it to escape the notice of its enemies.

Thus, however different in form or structure, the locomotive organs of the reptiles constantly agree with their mode of life, and a further examination of the passive or active defences of these animals shows us that everywhere the want of some faculty is compensated by the possession of another.

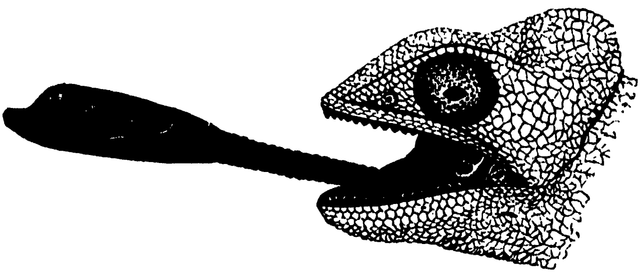
The large American iguana, for instance, when overtaken by one of its arch-enemies, the various species of the formidable cat tribe, makes use of its long and powerful tail as a most effective weapon of defence, lashing about with it to the right and left in such a manner as to make even the jaguar pause in his attack. When the monitor-lizard is pursued by the huntsman, it runs as fast as it can to its burrow; but when intercepted in its flight, it defends itself courageously. Its sharp teeth are able to bite through a strong boot, and its powerful tail sends the dog whom it hits howling from the field of battle, or lays him prostrate in the dust. Besides the activity of their movements, which enables them to dart suddenly from their place of concealment upon the beetles flies or gnats on which they principally feed, the insectivorous lizards are furnished with an extensile tongue, fissured at the extremity,

To face p. 274.



and thus forming an excellent apparatus wherewith to catch their prey.

But perhaps in no animal is this organ more remarkable than in the chameleon, where by its extraordinary power of extension, and by the rapidity of its movements, it is made to compensate for the extreme sluggishness which characterises the muscular system of that singular creature. The chameleon, fixed firmly by means of its bifid feet and prehensile tail upon the bough of a tree, has no occasion to move in quest of insect prey, but waits patiently until its victims approach sufficiently near to be within reach of its tongue, which, though generally



Tongue of Chameleon.

concealed within the cavity of the mouth, is capable of being elongated until it exceeds in length the whole body of the animal. No sooner does a fly approach within five or six inches of the chameleon, than the tongue is slowly protruded for the length of about an inch, so as to expose its thick fleshy extremity, the end of which is divided into two prominent lips, and copiously lubricated with a thick viscid secretion. The whole tongue is then launched out, with a rapidity that is perfectly amazing, to the length of six or seven inches, and a fly glued to its extremity is brought into the creature's mouth so quickly, that the eye can scarcely follow the movement.

Besides the possession of this unique tongue, the chameleon is very much assisted in its chase after insects by its singular faculty of voluntarily changing colour, which enables it to conceal itself by adopting that of the branches around, and by the peculiar structure of its enormously projecting eyes. Although the movements of its head are very limited on account of the

shortness of its stiff neck, this deficiency is amply compensated by the wide range of its vision, each eye being able to move about in all directions independently of the other. Thus, while one of them gazes upon the heavens, the other minutely examines the ground; or while one of them rolls in its orbit, the other remains fixed: nay, their mobility is so great, that without even moving his stiff head, this wonderful saurian, like Janus, the double-faced god of ancient Rome, can see at the same time all that goes on before and behind him. This mutual independence of the eyes is owing to the imperfect sympathy which subsists between the two lobes of the brain and the two sets of nerves which ramify throughout the opposite sides of its frame. Hence, also, one side of the body may be asleep while the other is vigilant—one may be green while the other is ash-blue; and it is even said that the chameleon is utterly unable to swim, because the muscles of both sides are incapable of acting in concert. Thus, whatever to the ignorant eye seems strange or grotesque in the organisation of the chameleon, is in reality most admirably adapted to its wants.

In the crocodile the structure of the tongue is no less remarkable than in the chameleon, though of a very different character; as, far from being extensile, it has not even a moveable extremity, but is attached by its whole circumference to the under-jaw. At the posterior part of the organ a broad fold of the skin can be applied against a corresponding fold of the palatal membrane that descends from the roof of the mouth, so that the two when approximated form a valve that completely closes the communication between the mouth and the posterior fauces. By this curious and provident arrangement, the crocodile is enabled to keep its mouth open under water, without danger of suffocation from that fluid getting into its windpipe; whilst by means of its long tubular nostrils, which open at the very apex of its snout and are continued backwards to behind the valvular apparatus above described, it is enabled to breathe with facility whilst only the tip of its nose is above the surface of the water.

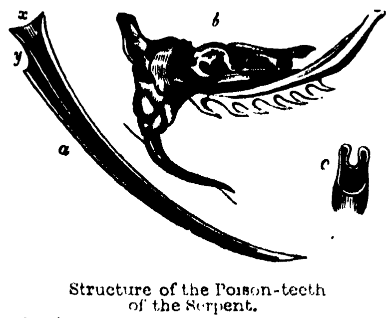
As the crocodile preys chiefly on fish, it is admirably organised for swimming, by means of its long oarlike tail, and its short strong webfooted legs; while the length of the body, which materially assists its progression in the water, renders it unwieldy on land. Thus this large and ferocious monster, which when full-

grown is more than a match for any of its enemies, is prevented by the wise ordinance of Providence from becoming as formidable on land as in the water; for when on shore the difficulty it has in turning, or of advancing otherwise than directly forward, enables men and animals readily to escape from it.

The colossal pythons and boas require no other means for overpowering the assaults of their enemies or the resistance of their prey than their prodigious muscular strength, for even the tiger and the jaguar are unable to resist their murderous embrace. They climb trees with great facility, the scuta of various segments through their enormous length laying hold of the bark, and aided by the great flexibility of their vertebral column, they are enabled to ascend in opposition to the force of gravity.

They select trees in the vicinity of streams and rivers, and suspending themselves from the branches in an inverted position by means of their prehensile tail, seize and crush quadrupeds even of great size as they approach to drink.

The active colubridæ, all of which are perfectly innoxious, dart suddenly upon the insects, lizards, or mice, for whom they lie in wait among the bushes or in heaps of rubbish, or escape from their enemies with wonderful velocity; while the venomous snakes, which are generally slow and indolent in their motions, and would thus become an easy prey to their enemies, have been endowed, as a compensation for their sluggishness, with so formidable a weapon as to make even the boldest opponent quail at their sight—for the slightest scratch of one of their fangs is certain death. A small canal runs through the centre of a great part of these needle-like teeth, and opening in a groove near the apex, terminates on the anterior surface in an elongated fissure. Towards the basis of the tooth a similar slight groove or longitudinal indentation communicates with the duct of the poison-gland. This is



Structure of the Poison-teeth of the Serpent.
a longitudinal section of poison-fang, *b* shows a hair inserted into the poison-canal, *c* transverse section of fang, *x* pulp-cavity, *y* poison-canal.

surrounded by a double aponeurotic capsule, of which the outermost and strongest layer is in connexion with a muscle, by whose contraction the gland is compressed and emptied of its secretion, which is thus conveyed by the duct to the basal aperture of the poison-canal of the fang. We may suppose that as the analogous salivary glands in other animals are most active under particular emotions, the rage or hunger which stimulates the venom-snake to use its deadly weapon must be accompanied with an increased secretion and great distension of the poison-glands; and, as the action of the compressing muscles is contemporaneous with the blow by which the serpent inflicts its wound, the poison is at the same moment injected with force into the wound by the apicial outlet of the perforated fang.

Strange to say, this deadly liquid has no acrid or burning taste or smell to announce its fatal properties; the tongue would pronounce it inoffensive, and it can even be swallowed with impunity; yet the smallest quantity introduced into an open wound suffices to dissolve the blood, and to paralyse the stream of life with an almost incredible rapidity. No chemist has yet been able to solve the enigma of its action, to explain the reason of its deadly effects!

Had the poison-fangs been immoveably fixed they would have been great hindrances to the act of swallowing, but this inconvenience has been obviated by the great mobility of the superior maxillary bone to which they are attached, so that they can voluntarily either be concealed in the gum with their point turned backwards, or pushed forwards and erected.

Lancets of needle-like dimensions must necessarily be fragile, but here also precautions have been taken against an irreparable loss, as an aftergrowth of supplementary fangs is constantly in readiness to replace them when broken. Thus even the terrible poison apparatus of the viper is full of wonders, and equally worthy of admiration and of fear.

In spite of their proverbial 'wisdom' and the frequent possession of a weapon of such annihilating power, the serpents, among whose two hundred and sixty-three known species fifty-seven are venomous, would never have been able to maintain their existence had they not possessed the faculty of swallowing at one meal enormous masses of animal food.

For although generally agile in their movements, the deer, rodents, lizards, or insects on which they feed, according to their size, are frequently still more active, and thus they are obliged to lie in wait and seize the favourable opportunity for darting unawares upon their prey. This is frequently of a more considerable volume than the body of its captor, and as their small teeth are incapable of diminishing or masticating their food, they would have been condemned to perish in the midst of abundance had not their mouth been capable of enormous distension. For this purpose the two sides of the lower jaw do not coalesce like ours into one solid mass, but are only loosely connected with each other, thus allowing each part to be moved separately. The bones of the upper jaw and palate are also loosely attached or articulated one with the other by ligaments, so as to allow the aperture of the mouth to be considerably widened.

By this mechanism, aided by the numerous sharp teeth which are generally fixed both in the jaws and on the roof of the mouth, and, having their points curved backwards, serve as so many little hooks for seizing and holding their prey, each side of the jaws and mouth, being able to act as it were independently of the other, alternately hooks itself fast to the morsel or advances to fasten itself farther on in a similar manner; and thus the reptile draws itself over its prey, somewhat in the same way as we draw a stocking over our leg, after having first, by breaking the bones, fashioned it into a convenient mass and rendered its passage more easy by lubricating it with its saliva. Slowly the huge lump disappears behind the widening jaws, descends lower and lower beneath the scales, which seem ready to burst asunder with distension, and then the satisfied monster coils himself up once more to digest his meal in quiet. The time required for this purpose varies of course according to the size of the morsel; but often weeks or even months will pass before a python rouses himself from the lethargic repose in which he lies plunged after a superabundant meal.

While the venomous snakes are armed with formidable fangs, and most other serpents are well furnished with teeth, those of the genus Deirodon are so small as to be scarcely perceptible. An acquaintance with the habits and food of this species has shown how admirably the apparent defect is adapted to its wellbeing.

Its business is to restrain the undue increase of the smaller birds by devouring their eggs. Now, if the teeth had existed of the ordinary form and proportion in the jaws and palate, the egg would have been broken as soon as it was seized, and much of its nutritious contents would have escaped from the lipless mouth of the snake in the act of deglutition; but owing to the almost edentulous state of the jaws, the egg glides along the expanded opening unbroken; and it is not until it has reached the gullet, and the closed mouth prevents any escape of the nutritious matter, that the shell is exposed to instruments adapted for its perforation. These instruments consist of processes growing out of the last cervical vertebræ, the extremities of which are capped by a layer of hard cement, and penetrate into the interior of the œsophagus. The shell being sawed open longitudinally by these vertebral teeth, the egg is crushed by the contractions of the gullet and is carried to the stomach, where the shell is no doubt soon dissolved by the acid gastric juice.

The intellectual powers of the reptiles are confined to very narrow limits, yet these lowminded animals possess many of the passions and instincts which we have had occasion to observe among the fishes. The same imperative impulse which forces the salmon to quit the salt-waters of the ocean and ascend the rivers, compels also the turtles at the beginning of the dry season to seek the sandy shores of desert islands or solitary bays, or directs the marsh and river-tortoises to the warm flat islands which dot the surface or crowd about the estuaries of the colossal tropical streams. There they select a place in which their eggs can be hatched by the heat of the sun, and dig holes before depositing them for their protection. As soon as they burst their shell, the young immediately crawl towards the water, in obedience to the instinct which tells them that this is their proper element, and that the dry sands, after having once done their office in bringing them to life, can afford them neither security nor food.

The lacertine and ophidian tribes also select proper places for their eggs, either in the warm sand or in heaps of fermenting substances. Thus several of the American alligators, after having scraped together a little mound on the banks of rivers, hollow it out in the middle and fill up the rest with vegetable matter, as if a professor of chemistry had taught them that the process of

putrefaction engenders heat. One species of salamander commits a single egg to a leaf of persicaria, protects it by carefully doubling the leaf, and then proceeding to another, repeats this manœuvre till her whole stock is provided for.

Nor are the reptiles so totally devoid of all sentiments of affection as is commonly supposed. The Singhalese remark that if one cobra be destroyed near a house, its companion is almost certain to be discovered immediately after; and Pliny notices the affection that subsists between the male and the female asp, and that if one of them happen to be killed, the other seeks to avenge its death. The she-alligator watches over the safety of her young for a long time after their birth, and endeavours to protect them from her voracious mate, who it must be confessed has but little of a father's tenderness; and the male iguana is strongly attached to the female, whom he will defend with the most obstinate fury. Even the ill-famed crocodile appears to be better than its reputation—instances having been quoted of its becoming tame and in some degree gentle to its keeper.

Of the memory of lizards we find a curious instance in Sir E. Tennent's 'Sketches of the Natural History of Ceylon.' In the officers' quarters in the Fort of Colombo, a gecko had been taught to come daily to the dinner-table, and always made its appearance along with the dessert. The family were absent for some months, during which the house underwent extensive repairs, the roof having been raised, the walls stuccoed, and the ceilings whitened. It was naturally surmised that so long a suspension of its accustomed habits would have led to the disappearance of the little lizard; but on the return of its old friends, it made its entrance as usual at their first dinner the instant the cloth was removed.

Although frogs are found both at the mouths of the Mackenzie and at the Straits of Magellan, and lizards dwell both in Scotland and Kamtschatka, yet the reptiles are chiefly confined to the tropics, as from their cold blood they are incapable of supporting a low temperature.

Were they possessed of wings, there can be no doubt that our northern snakes, lizards, frogs, and toads would fly to a warmer climate as soon as the first cold nights of autumn cover the meadows with a silvery sheet of hoarfrost; but though deprived of wings, these animals are taught by an admirable instinct to

brave the winter in their own domain, and to seek a refuge either underground, or under stones or timber, or under the bark of trees—where, sheltered from the cold, they sink into a deep lethargic sleep, which lasts until the first warm days of spring enable them to resume an active life.

The slow or blind worm (*Anguis fragilis*), as it is falsely called, its small brilliant eyes being capable of seeing very distinctly, burrows itself a complete winter residence, consisting of a tunnel from about thirty to thirty-six inches in length, the mouth of which it plugs up with grass and earth. Close to the entrance lie the young, farther on the more full-grown snakes, and finally in a small recess an old male and female—the patriarchs of the community, which frequently consists of twenty or thirty individuals, all in a deep trance—partly twisted together, partly stretched out at full length.

In the equatorial regions the extreme aridity of the dry season is as hostile to animal life as the extreme cold of the north. Thus many reptiles, unable to procure their ordinary food from the drying-up of the watercourses, must necessarily have perished, had not an admirable instinct prompted and their organisation allowed them to bury themselves in the mud, and remain in a state of torpor till released by the recurrence of rain.

Sir Emerson Tennent, whilst riding across the parched bed of a tank, was shown the recess still bearing the form and impress of a crocodile, out of which the animal had been seen to emerge the day before. A story was also related to him of an officer who, having pitched his tent in a similar position, was disturbed during the night by feeling a movement of the earth below his bed, from which on the following day a crocodile emerged, making its appearance from beneath the matting.

After the first rains have moistened the arid llanos, the parched clay of the dried-up morass is sometimes seen to rise as if upheaved by subterranean power. The Indian, fully aware of the cause, takes to flight, for a gigantic water-boa or a huge crocodile is slowly arising from the tomb in which it had voluntarily embedded itself.

Man generally avoids the reptiles, which are equally solicitous to fly from his presence; and yet they are far more useful than noxious. They devour an immense quantity of mice, insects, worms and snails, and in many countries their services as de-

Several of the reptiles afford an equally agreeable and healthy food. The flesh of the turtle needs no special encomium; one single specimen of the elephantine tortoise of the Galapagos will provide a ship's company with a supply of *fresh meat for* several weeks; and the common or Greek tortoise, which also renders good services in gardens by the destruction of insects, is frequently brought upon the provision market in the coast towns of the Mediterranean.

The white flesh of the iguana is one of the great delicacies of the West Indies, and on the Continent frogs' legs are the epicure's delight. But it is not merely as food that the reptiles are valuable to man: tortoise-shell—which ought rather to be called turtle-shell, as it is furnished by a denizen of the ocean (Hawksbill-turtle)—is one of the most elegant articles for various ornamental purposes, and the tough skin of the crocodiles and alligators make excellent sandals and saddles.

On comparing with all these services the injuries which the reptiles inflict upon man, it will be found that the balance inclines very much in favour of the former. It is but seldom that he falls a prey to crocodiles and alligators, or that the boa crushes him to death, or that the poison-fang of the rattlesnake dooms him to almost instantaneous destruction. No venomous snake will ever attack him unprovoked; the boas and pythons, far from seeking the opportunity of assailing him, are glad to escape his notice; and the crocodiles are so awkward on land that they are but little inclined to seek their prey out of the water.

Both the noxious and the far more numerous harmless reptiles are kept in check by a host of enemies. The storks, herons, and buzzards are constantly thinning their ranks; the ostrich

is a determined serpent-hunter; and the secretary-bird is so renowned for his exploits as a snake-killer that he has been introduced into the West Indies for the purpose of exterminating the terrible trigonocephalus, which, before he came to the rescue, rendered working in the sugar-plantations so dangerous to the negroes.

In their combats with the snakes the birds evince an admirable instinct. Thus the buzzard is fully aware of the dangerous bite of the adder, even when he has been caught quite young, and has never before seen one of these terrible reptiles. He aims at once at the head, and only begins to feast upon the body after having previously crushed it. Harmless serpents, on the

Mongoos (Herpestes Vitticollis).

contrary, he will hold a long time in his talons, enjoying their vain endeavours to escape or to molest their persecutor, and then bite them indiscriminately either in the tail or in the head. Who taught him this lesson?—who enabled him to distinguish between creatures apparently so similar?—who informed him that here only an impotent rage exhausts itself in ineffectual efforts, while there a deadly poison is to be avoided?

In the backwoods of America the rattlesnake everywhere disappears before the advance of man, as the hog, the squatter's invariable companion, is its most formidable enemy, whom it dreads so much that, on seeing one, it immediately loses all its

courage, and instantly takes to flight. But the hog, who smells it from afar, draws nearer and nearer, his bristles erect with excitement, seizes it by the neck, and devours it with great complacency, though without touching the head.

On account of his activity in destroying crocodile-eggs and snakes the ichneumon was ranked by the ancient Egyptians among their numerous divinities. The Indian mongoos also attacks without hesitation the most venomous serpents. The cobra, which puts even the leopard to flight, rises before the little creature with swelling hood and fury in its eye; but, swift as thought, the mongoos, avoiding the death-stroke of the projecting fangs, leaps upon its back, and, fastening his sharp teeth in the head, soon despatches the helpless snake.

Even in their own ranks the reptiles have many enemies, who take care to keep their numbers in check, and prevent them from acquiring a dangerous ascendancy over the other animals. Thus the Trionyx ferox, a river-tortoise of South Carolina, lies in wait among the rushes for the young alligators; and one serpent frequently devours the other.

Against these manifold attacks the reptile race maintains itself, not only by the various defences I have mentioned, but by a great fecundity. Frogs and toads often lay above twelve hundred eggs—tortoises and turtles above four hundred, during the course of the dry season—crocodiles and snakes from fifty to sixty. Thus the reptiles not only supply food to a vast number of animals, but keep on flourishing from generation to generation and from age to age.

CHAPTER XXVI.

BIRDS.

Their Wings and Rapidity of Flight—Quill-feathers—Wings of the Ostrich and the Penguin—Feathers—Rump-gland—Legs of Birds—Waders—Swimmers—Raptorial Birds—Perchers—Beaks of Birds—Black-skimmer—Boatbill—Spoonbill—Crossbill—The Flamingo's and the Toucan's Tongue—Digestive Apparatus of the Birds—Strength of Vision—Services of Birds—Nests of Birds—The Sand-martin—The Woodpecker—The Chaffinch—The Cassique—The Baltimore Oriole—Weaver-birds—The Baya—The Social Grossbeak—The Tailor-bird—The Tallegalla—The Sea-lark—Heroism of Birds in defending their Young—The Lämmergeier—Artifices of the Lapwing and Ostrich—Memory and Intelligence of Birds—Migratory Instinct.

When the word reptile is mentioned, a host of loathsome forms rises before our fancy. The slimy toad seems to distend its repulsive body, the wily adder hisses and menaces us with its venomous fangs, the boa uncoils its enormous folds to stifle us in its embrace, and the dreadful crocodile snaps at us with its formidable jaws.

How different the picture when our thoughts turn to the Birds, the light-winged denizens of the air! There all was dismal and dreary, clothed in dull melancholy tints such as befit the putrid swamp or the pestilential morass; here all is broad daylight and cheerful sunshine. The groves resound with harmonious voices; the brilliant hummingbird darts from flower to flower; the golden pheasant rears his beautiful crest; the swan, robed in his spotless garb, draws furrows through the crystal lake; the peacock, in the full consciousness of his beauty, strides proudly over the lawn; and high above, almost beyond the reach of human vision, the eagle sweeps in majestic circles through the sky.

Other animals likewise quit the solid earth, or the waters of the sea, to seek food, or refuge from their enemies, in the light

regions of the air; the buzzing bee and the silent butterfly hover from flower to flower; the flying-fish, darting into another element, eludes the dolphin's pursuit; and the bat, expanding his broad wings, wheels like a demon of the night in quest of his insect prey. But the low flight of all these creatures is confined either to a few moments, or to a narrow sphere; while the feathered races roam far and wide through the vast realms of the atmosphere, and defy both height and distance with their powerful and unwearied wings.

According to Humboldt, the condor soars to an elevation of 48,000 feet, from whence he would be able to overlook the whole of Great Britain and Ireland, and then again in a few minutes darts down to the level of the sea; the albatross, quietly facing the gale, bids defiance to the fury of the unshackled elements; and the frigate-bird, though frequently met with at the distance of four hundred leagues from land, is said to return every night to his solitary roost. To perform these prodigious flights, these monarchs of the air have been gifted with an enormous spread of wing. Thus the pinions of the albatross extend from ten to thirteen feet, and those of the condor and the frigate-bird measure even still more from end to end; but even among the smaller birds we find many that divide the air with an astonishing swiftness and length of flight. The carrier-pigeon has been known to travel in less than six hours from London to Liège in Belgium; the fleetest greyhound would be unable to overtake the swallow; and the tiny hummingbird, although generally averse to long migrations, darts from flower to flower with such lightning-like velocity, that the most attentive observer is unable to distinguish the rapid vibrations of its wings.

A glimpse at the organisation of the birds shows us how admirably they are constructed for an aërial life. As their wings, which correspond to the forefeet of the quadrupeds or to the arms of man, are in most cases the chief organs of locomotion, and their use consequently requires the greatest concentration of strength, their muscles are generally far more powerful than those of the legs. The breastbone is also enormously developed, so as to serve as a fit point of attachment for the muscular masses which set them in motion; and its dimensions correspond so exactly with the strength of the wings, that on comparing its size with that of the remaining skeleton, we can

at once judge of a bird's powers of flight. Thus in the ostrich and cassowary, whose wings are incapable of raising them into the air, the keel, or osseous crest—which in most birds arises from the centre of the breastbone, and serves to increase the surface of muscular attachment—is absent, while it projects enormously in the diurnal birds of prey, in the swallows, and in the hummingbirds.

To assist the action of the wings, they are provided with a crest of quill-feathers, more or less elongated, and decked with 'coverts' imbricating over each other like the tiles of a roof. When expanded, these feathers press like a light fan upon the elastic air-wave beneath, and considerably increase the surface of the bird without materially adding to his weight. Not only the size, but also the form and texture, of the quill-feathers has a material effect on the powers of flight. Thus in the falcons, each primary quill-feather is elongated, narrow, and gradually tapers to a point; the webs are entire, and the barbs closely and firmly connected together. In the owls, the plumage is loose and soft, and the outer edge of the primaries is serrated; so that while they are debarred from a rapid flight, which would be dangerous in the gloom in which they go abroad, they are enabled by the same mechanism to wing their way without noise, and steal unheard upon their prey. In the ostrich, the barbs of the quill-feathers have so little adhesion to each other, that the air can pass readily between them, and thus the wings, even by their most energetic action, are totally incapable of raising the bird from the ground. Their flapping, however, materially assists the action of the legs, and serves to increase the speed of the giant bird when, flying over the arid plain, he 'scorns the horse and his rider.'

The penguin is totally deprived of quill-feathers, like the cassowary or the kiwi; but, though incapable of flight, this strange bird makes use of its small featherless wing-stumps as excellent paddles in the water, and on land as forefeet, with whose help it scales so rapidly the grass-grown cliffs, as to be easily mistaken for a quadruped. Wherever great powers of flight have been given, they constantly correspond with some peculiar want. The food of the oceanic birds is to be sought for at a great distance from land; their prey, which consists entirely of marine animals, is constantly shifting its quarters, and it is

therefore necessary that their pursuers should be such perfect flyers as to be constantly on the wing, either following or seeking them. They also require a prodigious strength of wing either to brave the storm or to soar to such an elevation as to rise above its fury, like those Alpine travellers who from the serene height of a giant mountain look down upon the thunder-clouds below. Had not the swallows been endowed with a lightning-like rapidity, they would never have been able to catch a sufficient quantity of the insects, winged like themselves, on which they feed; and the tiny hummingbird, constantly hovering from flower to flower, must have fallen an easy prey to every more powerful carnivorous bird, if he had not been able to dart along with the swiftness of a meteor. Besides the expansive wings, the small head, the pointed beak, the long and pliant neck, the gently-swelling shoulder, the tapering tail (acting like the rudder of a ship, and enabling the bird to rise or fall, or remain in a horizontal position), are all wisely calculated to assist and accelerate motion through the yielding air.

The internal structure of birds is no less beautifully adapted to the same purposes: all the bones are thin, and frequently hollow; and all the muscles, except those which are appropriated to the purpose of moving the wings, are extremely delicate and light; the lungs are placed close to the backbone and ribs; the air, entering into them by a communication from the windpipe, passes through and is conveyed into a number of membranaceous cells, which occupy a considerable space of the breast and abdomen, and which can be voluntarily distended with air, like the bladder which enables the fishes to rise in their native element. The feathers with which the birds are invested are so appropriate to their mode of life, that anything more perfect cannot possibly be imagined. Not only are they peculiarly fitted by their lightness as a raiment for creatures destined to hover through the air, but from their being very bad conductors of heat they afford the birds the best protection even against the extremes of cold. Under the cover of its dense white plumage, the snow-goose braves the terrific winters of the North, and the Antarctic petrel endures the freezing winds of its inhospitable seas.

Even under the equatorial sun, the condor soars high above

the limits of perpetual snow: like the lämmergeier of the Alps, he roosts on pinnacles where even in summer nights the thermometer sinks many degrees below the freezing-point of water; but under their feathery mantle, these birds of prey feel not the cold. Even in the tropical forests the temperature of the air falls considerably after sunset, and then the parrot and the toucan, the tangara and the cotinga, enjoy the benefit of a vesture which prevents the heat of their bodies from radiating into the cold atmosphere.

To brave the rigours of the North, the eider-ducks are furnished, under their external cover of feathers, with a soft cushion of down, which serves them also to line their nest, and in many birds a lighter summer plumage alternates with a warmer winter covering.

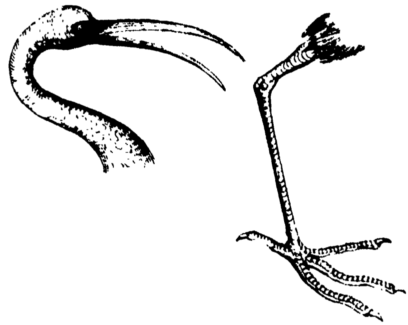
As but few birds sleep under cover, and many of them are exposed to every weather, they necessarily require a waterproof mantle. For this purpose they have been provided with a gland at the rump, from which they express an oily matter, which spread over the plumage renders it impermeable to the wet. The lubricating of their feathers with this unctuous fluid is one of the chief occupations of many birds, particularly of the water-fowl, in whom the gland by which it is secreted is, as might be expected, particularly large, while it is totally wanting in the ostrich, who in his arid home does not require its aid.

Admirable as a most appropriate vestment, the feathers of birds are scarcely less so from the splendour of their hues or the elegance of their arrangement. What an astonishing variety of shape and colour! The plumage of the colibri rivals the sapphire and the ruby in brilliancy. Which robe is most pleasing to the eye, that of the snow-white swan, or that of the scarlet macaw? And who has the richest raiment, the bird of paradise of New Guinea, or the mandarin-duck of the Chinese lakes? Can anything surpass the beauty of the menura's tail, the diadem of the tody, or the gorgeous train of the peacock? Among such a host of competitors, it is difficult indeed to award the prize, or to select a prime favourite among so many forms of beauty.

An examination of the legs of birds opens new wonders to our view, for here also we see masterpieces of adaptation of means to end. Thus in the ostriches and cassowaries—who, unable

to fly, would otherwise have been left without defence against the more powerful beasts of prey—they are extremely robust and muscular, so as to enable these colossal birds to scour the sandy plains with such velocity, that their feet scarcely appear to touch the ground.

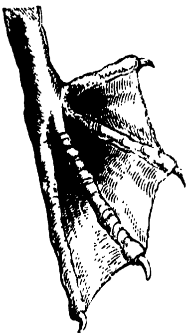
In the waders, who are also most excellent runners, they are not so strongly built, but their uncommon length is extremely well-suited for walking on swampy ground, or for fording shallow estuaries and marshes. A greater muscular strength would have been superfluous, as the body they have to carry is proportionably small and light, and, besides, a more robust construction could only have been obtained by a greater weight, which would have been a serious inconvenience to birds which pass so great a part of their lives on a treacherous and unstable soil.


Head and Leg of the Ibis.

Planted in the centre of the body, they are thus enabled to carry its equally-distributed weight with the least possible amount of exertion; and as they are only feathered as far as the middle of the thigh, they are the better enabled to wade deep into the water, particularly as their straight and elongated toes, which are also frequently lobed or webbed, prevent them from sinking too deeply into the mud.

A most remarkable example of the provident care with which the formation of the toes of the waders has in every case been adapted to the peculiar circumstances of their life, is afforded us by the yacana, in which they are distinguished by extraordinary length, and armed, moreover, with equally long spinelike claws, especially that of the hinder toe. For a bird destined to pace the ground, toes such as these would have been as inconvenient as the snow-shoes of a Laplander; but to the Tacana they are extremely serviceable, as from the wide surface over which they extend, they enable this extremely light bird to pursue its food, consisting of

worms, small fishes, and insects, by walking unsubmerged on the leaves of aquatic plants which float on the water. In the Swimmers or Palmipeds, the legs are as beautifully adapted for cleaving the water, as in the Waders for marching over a swampy ground.

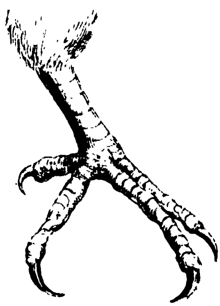


Foot of the Pelican.

The toes are webbed so as to form a broad oarlike surface, and the short and muscular legs are placed behind the point of equilibrium—a peculiarity which occasions an awkward gait on land, but is extremely favourable to birds 'whose business is in the deep waters.'

In the birds of prey the legs are likewise robust and short, but here the toes are armed with long, strong, and crooked talons, so as to be able to tear their prey, and carry it easily to the lofty situations in which they build their nests. For this reason the eagles have been endowed with comparatively far stronger legs and claws than the owls, whose prey consists only of small birds, mice, or even insects, and who are not obliged to carry it to high rocks and mountain pinnacles.

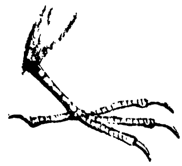
Talons of a Bird of Prey.



Foot of the Woodpecker.

In the scansorial birds—the woodpeckers and parrots—we find the feet with two toes before and two behind; a disposition which, though it proportionably impedes their progress on level ground, and would, for instance, have been highly inconvenient to the ostrich, gives them great facility in climbing the branches of trees, or ascending perpendicular stems.

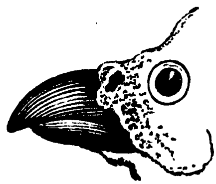
The strong and muscular legs of the gallinaceous birds, with three toes before, furnished with short, blunt, and robust nails, render them good service in scratching up their food, which mostly consists of grains and seeds; while the slender and short feet of the perchers, being more especially adapted to the delicate labours of nidification, have flexible and moderately-elongated toes, with long, pointed, and slightly-curved claws.


Foot of a Percher.

The beak of birds shows us, in its various forms, the same wisdom of plan and construction. In the birds of prey it is strong, curved, sharp-edged, and sharp-pointed, and often armed with a lateral tooth; in the eagles, however, where it is destined to lacerate a living prey, and has consequently to overcome a greater resistance, it is more powerful than in the carrion-feeding vultures; and were we to examine all the species of the raptores, from the smallest falcon to the imperial eagle, and from the burrowing owl to the highflying condor, we should find that in every case it is exactly suited in strength and form to the bird's peculiar prey or food. In the woodpeckers, the end of the large and strong bill is sharp and formed like a wedge, so as to be able to pierce the bark of trees, and penetrate through the outside sound wood of the tree to the inside decayed part, where the food is lodged; and in the parrots, we find the upper mandible terminating in a strong tooth, and curving over the smaller lower mandible, equally well adapted for cracking the hardest nuts.


Head of Falcon.

Those sea-birds which live upon fishes too large to be swallowed whole, have compressed beaks, with sharp edges, and a hooked extremity similar to that of the birds of prey, where, however, it is comparatively shorter and stronger; while in the storks and cranes, which feed on smaller fishes and reptiles, it is generally straight, and longer than the head, like a pair of tongs—a form well adapted for seizing a prey that seeks concealment on a muddy ground. The hardness of the bill invariably corresponds with the resistance to be overcome; thus in the larger species of woodpeckers it acquires the hardness of ivory, while it changes to a soft skin in those



Beak of the Guineafowl.

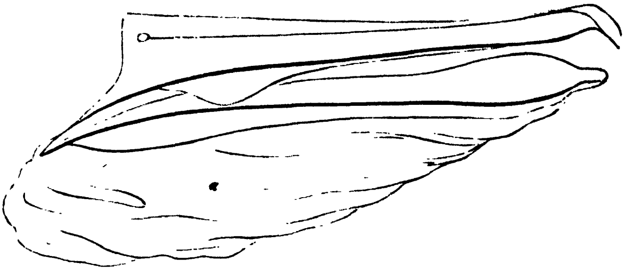
serves to pick up with due rapidity the vegetable seeds or grains, as well as the worms or grubs they scratch up out of the ground; while the bills of the small Insessorial or Passerine birds present every gradation of the conical form, so as to correspond with their various habits. The short and strong-billed crows and finches live on seeds and grains; the beaks of the shrikes and flycatchers are more or less notched, curved, or emarginated at the point, so as to be able to dismember the small birds, mice, or insects on which they feed; the hummingbirds have an extremely long and slender bill, with which they extract ants, flies, or nectareous juices from the very bottom of the long tubular corollas so common among the tropical flowers; and the goat-suckers and swallows, who are in the habit of catching and devouring insects on the wing, have a very short and very deeply-cleft beak, which enables them to receive their prey in full flight into the cavity of their mouth, while frequently a viscous exudation within, and a strong fence of vibrissæ on the exterior, assist in securing the victim.

Rostrum of a Crow.

Long-tailed Hummingbird.

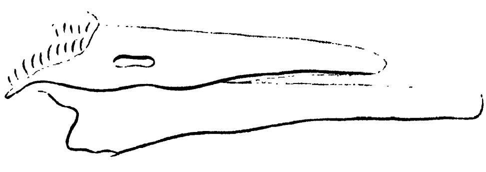
In many cases the bill presents a strange anomaly of form, as if Nature had indulged in some wild vagary or caprice; but on a closer inspection it will almost invariably be found that these deviations from the ordinary types are of great use to their possessors.

The naked elastic pouch (*a*), depending from the two bony branches of the lower mandible of the pelican's bill, enables the bird to dispose of the superfluous quantity which may be taken during fishing-excursions, either for its own consumption

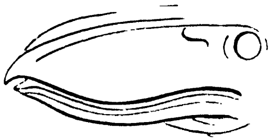


or for the nourishment of its young, while the nail or very strong hook of the upper mandible is of great assistance in securing its slippery prey.

The bill of the black skimmer or cutwater is quite unique in its kind; the under mandible, which is in fact nothing but a wedge, being about an inch longer than the upper one, by which it is clasped.



With this curious apparatus the bird, while on wing, skims the surface of the sea in search of small fish, shrimps, or young fry, whose usual haunts are near the shore and towards the surface, dipping only the sharp under-mandible into the water, while the upper mandible is raised above. A vast expansion of wing enables it to sail along with sufficient speed, so that whoever (says Wilson) has observed the facility with which the rynchops procures his food, cannot but consider it a mere playful amusement, when compared with the dashing immersions of the tern, the gull, or the fish-hawk, which to the superficial observer appear so much better equipped.



Beak of the Boatbill.

The boatbill owes his name to his very remarkable beak, resembling a boat with its keel upwards; the mandibles are very stout and sharp-edged, and the upper one has a projecting point at the extremity. This strangely-formed bill is as serviceable to its possessor, in seizing the fish upon which he pounces from his seat on the branches of trees by the side of rivers, as is the long and flat beak of the spoonbill in fishing for small crustaceans and molluscs along the edges of the water, or in the mud left exposed by the ebbing tide.

Beak of the Spoonbill.

Avoset. Recurvirostra Avocetta.

The bill of the avoset, which is about three times as long as the head, turns up like a hook in an opposite direction to that of the hawk or parrot, and is flat, thin, sharp, and flexible like whalebone. An instrument like this would of course have been very unfit for cracking nuts, picking up grain, or lacerating a larger prey, but it answers admirably for scooping smaller marine animals out of the sand or from among the pebbles of the shore.

The toucans and hornbills are remarkable for the enormous size of their bill, which is sometimes equal to that of the body itself, and might seem rather adapted to birds of ostrich-like dimensions than to volatiles not much bigger than crows. Were they of a strong and solid texture, these huge beaks would infallibly weigh them to the ground; but being of extremely light and cellular structure the birds carry them easily, and leap with such agility from bough to bough, that they do not then appear preposterously large.

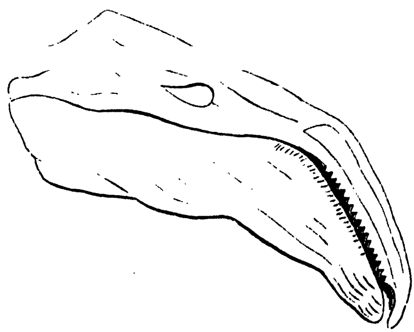
Of all beaks, perhaps the most extraordinary is that of the crossbill, in which the extremities of the mandibles curve towards opposite sides, and cross each other at a considerable angle; a disposition which, at first sight, seems so opposed to the natural intention of a bill, that even Buffon characterised it as an error and defect of nature, and a useless deformity.

But a more accurate observation has shown that this apparently awkward shape is in fact most admirably adapted to the habits of the bird. For the crossbills live mostly on the seeds of the cones of the fir, in procuring which they exhibit wonderful instinct, as, holding the cone in their claws, they bring the points of their beak immediately over each other, and insinuate them between the scales, when, forcing them laterally, the scales open, and then again bringing the points in contact, they pick out the seed with the utmost ease.

Crossbill (Loxia Curvirostra).

Thus, where even an eminent naturalist ventured to find fault, we meet with a most beautiful and interesting example of Divine foresight and wisdom, which may well teach us to be humble and cautious in attempting to question His ways, or to pass judgment on His works.

The flamingo, one of the most remarkable of all the aquatic birds for its beauty, and the great length of its neck and legs, is also possessed of a most singularly-formed beak, nearly seven inches long, higher than broad, and suddenly curved downwards from the middle. This extraordinary shape corresponds with an equally extraordinary mode of feeding, for when fishing for its prey in the teeming shallows, the flamingo twists its long neck in such a manner that the upper part of its bill is applied to the ground, while the trampling feet at the same time disturb the water, so as to raise up the worms, molluscs, or crustaceans which form the bird's repast.

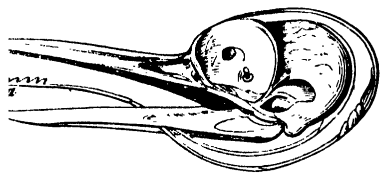


Bill of the Flamingo.

The structure of the tongue assists in an admirable manner the action of the bill and feet, for the spines with which its upper surface is armed are arranged in an irregular and alternate series, and act with the notches on the edge of the upper mandible, in which they press when the bird feeds with the

head reversed. In this position the weight and size of the tongue become a very efficient instrument for entrapping the food. The bird waddles and clatters the bill, and dabbles about, and the tongue receives and holds as a strainer whatever the water offers of food.

In many of the insectivorous birds the tongue is equally well adapted for seizing its nimble prey before it has time to secrete itself in some impenetrable citadel. Thus after the strong beak of the woodpecker has dislodged the insects from their hiding-places, they are immediately transfixed with the hard, horny, and sharp point of its tongue (*a*), which it is capable of darting forth with amazing rapidity, and held fast by the sharp-pointed processes directed backwards, which arm its sides and thus convert it into a barbed harpoon.



Cranium and Tongue of a Woodpecker.

In the hummingbirds it is divided at its extremity into a pencil of fine hairs, well-fitted for imbibing the nectar and farina of flowers; while in the toucan, stiff

Tongue of the Toucan.

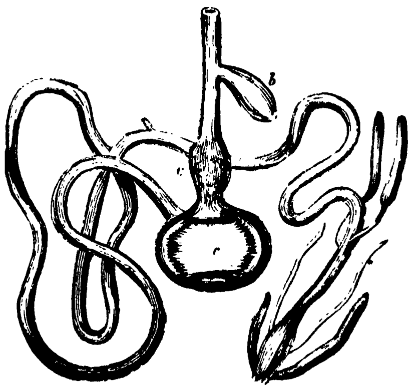
bristle-like processes project forwards from its sides, and the tongue so provided becomes an instrument for testing the softness and ripeness of fruit, and the fitness of other objects for food, thereby acting as a kind of antenna or feeler.

In the parrots it is thick and fleshy, serving admirably to keep steady the nut or seed upon which the strength of the mandibles is exerted, and is applied to the kernel so extracted, as if to ascertain its sapid qualities.

The birds are unable to chew or masticate, but this defect is amply supplied by the peculiar construction of their digestive apparatus, which in every case is admirably modified, according to the nature or volume of the food. Thus in those species which devour but small quantities at a time, and without any considerable intermission, or where the aliments are of easy

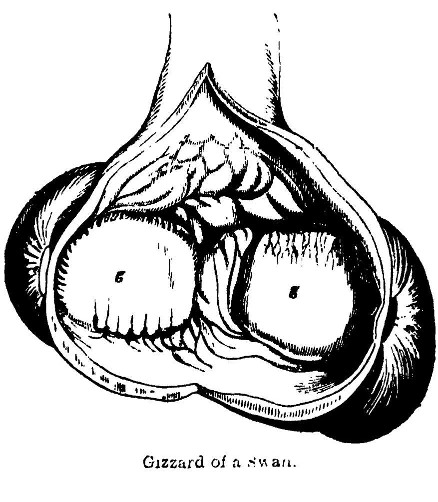
digestion, the gullet presents no enlargement; while in the eagles and vultures, which gorge themselves at uncertain intervals from bulky carcasses, it undergoes a lateral dilatation, to serve as a temporary reservoir or macerating apparatus.

In those birds whose food consists of grains and seeds this enlargement or crop is still further developed, and assumes the form of a large-sized single pouch (*b*), as in the fowl, or of a double one, as in the pigeon. Here the food will frequently remain for sixteen or twenty hours, until it becomes softened with the abundant secretion of the salivary glands; and being thus duly prepared, it passes on to the proventriculus (*c*), the first or glandular division of the stomach, where it is submitted to the solvent action of the gastric juice. The proventriculus varies in form and magnitude in different birds, but is largest in those which have no crop, as if to compensate for the want of this preparatory macerating cavity.



Digestive Apparatus of the Common Fowl.

The third and last act of the digestive process is performed in the gizzard (*e*), which in the birds of prey assumes the form of a mere membranous sack, in accordance with the animal and easily digestible nature of their food; but in those which devour thick-coated seeds or other hard substances, it is of so dense a texture, that its horny callous sides (*g g*) are able to grind the aliments as between two millstones.



Gizzard of a Swan.

The cavity of the gizzard being necessarily very small, a crop is as essential an appendage to this structure as the 'hopper' to the mill; it receives the food as it is swallowed, and supplies it to the gizzard in small successive quantities as it is wanted. To assist the triturating power of the gizzard, the birds have been taught by an admirable instinct to swallow hard foreign bodies, such as sand, gravel, or pebbles. Fowls grow lean if deprived of stones, and no wonder, since experiment shows that, unless the grains of corn are bruised and deprived of their vitality, the gastric juice will not act upon or dissolve them.

Birds necessarily require an uncommon strength of vision, both for discovering their prey and avoiding their enemies; for their prey is frequently small, and not easily to be distinguished from the surrounding objects, or is itself engaged in rapid motion, so that often even the greatest velocity of flight would have been unavailing, without the assistance of a piercing eye. A bird hovering in the air can be seen from a vast distance by a sharp-sighted enemy, and thus also needs a keen vision, to be able to escape in due time from the impending danger.

Besides the faculty of embracing a vast field of vision is the essential adjunct of considerable powers of locomotion; for it is evident that short-sighted and at the same time swiftly-flying birds must soon have perished from this want of harmony in their structure, their obtuse vision being a constant impediment to the full exercise of their vigorous wings.

For all these reasons the birds have been gifted with a sharpness of vision vastly superior to that of the quadrupeds. A sparrow will detect a grain of corn at the distance of eighty feet; a hawk soaring in the air distinguishes a lark from the similarly-coloured ground ten times farther than the eye of man or dog can reach; and from a height at which he himself is totally lost to human vision, the falcon pounces down upon the lizard or the field-mouse which he has chosen for his repast.

Sweeping in majestic circles through the skies, the lämmergeier embraces at a glance a whole world of Alpine solitudes and glaciers. The quadrupeds which inhabit these high regions—the goat or the chamois—heedlessly graze the mountain herbage, unconscious of the enemy above; but suddenly, with folded

wings, the monarch of the air sweeps down upon them like a meteor, and, even before they can think of flight, bears them aloft in his talons.

Scattered in countless numbers over all the lands and seas, from the poles to the equator, the birds occupy a conspicuous rank in organic creation. They may well be called the guardian-angels of the forest and the field; for though they consume many of the fruits of the earth, yet the damage they may cause is far outweighed by their services in clearing the woods and meads of hosts of insects, which but for them would gain a fatal preponderance over the vegetable world. Thus indirectly useful to man, they offer him, moreover, the tribute of their soft feathers, their savoury eggs, their nutritious flesh, or their fertilising guano; and not only largely add to his wealth or to his comfort, but contribute also to his spiritual or immaterial enjoyments; for without their enlivening presence our groves would be but gloomy solitudes, and even the loveliest landscape would lose half its charms in the absence of the feathered songsters.

The birds are also the soul, the life of stormy coasts and lonely islands; they animate the surf-beaten rocks, and the boundless wastes of the high seas. Far to the north, or in the unfrequented deserts of the Antarctic waters, on shores where no human being dwells, their cries are heard mingling in wild but not inharmonious concert with the hoarse rolling of the surge and the moaning wind; and hundreds of miles from land the mariner hails with delight the high-soaring frigate-bird, or the indefatigable albatross, winging his flight or hovering with graceful ease over the agitated ocean.

Even above the highest mountain-tops, where vegetation has long ceased, and the naked rock or snowclad pinnacle alone occupies the dreary scene, man still finds birds to cheer his solitary path; for the lämmergeier and the condor sweep in circles thousands of feet above Chimborazo or Mont Blanc, and high over the giant peaks of Kintschingow and Kintschinginga, flocks of wild geese are seen to migrate to unknown regions.

Thus, wherever he turns, man derives either profit or pleasure from the company of birds; and everywhere, in the woods and in the fields, on the plains and on the mountains, on the coasts and on the high seas, he welcomes them as friends.

Although most birds are able to seek refuge in an element where none but those of their own class—their most dangerous enemies with the exception of man—can pursue them, yet they are exposed to the attacks of many terrestrial animals. The martens and weasels, a number of rodents, the smaller felidæ and the tree-snakes, are constantly endeavouring to surprise them in their retreats; and even still more ignoble foes imperil their safety, for the brilliant hummingbird has been seen to expire under the jaws of the hideous trapdoor spider. Thus they are encompassed with dangers on all sides, both during their aërial flight and when they seek repose on land; but they are chiefly menaced in their eggs or their callow young, who, incapable of flight and self-defence, have nothing but the tenderness and the foresight of their parents to rely upon. But never has confidence been better placed; for Providence, which in every case proportions the means of resistance to the greatness of the peril, and nowhere shows its power more evidently than in the protection of the weak, has inspired the birds with a more than common share of affection for their helpless young, and taught them to build those wonderful homes without hands, where they bring up their dearest treasures with such touching self-denial, and in case of need defend them with such heroic courage.

The situations where the birds place their nests are as various as the materials of which they compose them, or the degrees of skill they evince in their construction. Many, for better protection against wind and weather, fix themselves in the deserted burrows of quadrupeds, or dig tunnels on their own account. Thus the gregarious sand-martin perforates steep gravelly or sandy banks, whose hardness frequently seems quite out of proportion to its tiny bill. But perseverance will do wonders; for turning round and round upon its legs as upon a pivot, and pecking away as it proceeds, the martin soon chips out a tolerably circular hole, which it prolongs to a depth of two or three feet with a gentle upward slope, so as to prevent the lodgment of rain.

At the farthest extremity is placed the nest—which, as an effectual protection has been already obtained, is a very primitive structure, hardly better than a mass of dry herbage and soft feathers. The burrowing puffin takes even less trouble

than this, for having dug its hole, it simply lays its eggs on the earth at the extremity; while the sheldrake, more regardful of the comfort of her young, lays them on down picked from her own breast.

Other birds establish themselves in the trunks of trees, and,

The Sand-Martin.

like the earth-burrowers, either form their tunnels with their own beaks, or appropriate to their use the excavations made by other animals, or the hollows formed by natural decay. Among these dendrobites, the woodpeckers, who by means of their pickaxe-like beak scoop out deep caves in decaying trees, or even in sound wood, hold a conspicuous rank. These nests are frequently most ingenious, the burrow sloping for six or eight inches, and then being driven perpendicularly down the tree.

The bird takes care to make the sloping tunnel only just large enough to admit the passage of its body, so as to render its defence more easy, but the perpendicular hole in which it resides is quite large and roomy, so as to deserve the name of a chamber.

Many European birds, such as the chaffinch or the pensile warbler, are remarkable for the neatness or ingenious construction of their dwellings. 'The nest of the chaffinch,' says the late venerable sage of Walton Hall, 'is a paragon of perfection. He attaches lichens to the outside of it by means of the spider's slender web. In the year 1805, when I was on a plantation in Guiana, I saw the hummingbird making use of the spider's web in its nidification, and then the thought struck me that our chaffinch might probably make use of it too. On my return to Europe, I watched a chaffinch busy at its nest; it left it and flew to an old wall, took a cobweb from it, then conveyed it to its nest, and interwove it with the lichen on the outside of it. The pensile warbler shows equal architectural skill;

her nest is formed of dry blades of grass, the ribs of leaves, and very small roots, all twined together in the most ingenious manner into a compact ball, and suspended to a netting which she has previously drawn from tree to tree, so that this curiously-constructed mansion rocks to and fro with the wind, secure from the assaults of her numerous enemies.'

But however skilful our native workmen may be, their constructions are surpassed by those of many of their relatives in the torrid zone, where a more energetic development of animal life naturally renders the struggle for existence more intense, and increases the danger to which every species is subject. Thus the American cassiques suspend their large pendulous nests, which often exceed a yard in length, at the extremities of lofty branches, as far as possible from all enemies that might by climbing reach the brood; and frequently choose, for still further protection, trees on which the wasps or maribondas have already built their nests, for these are adversaries whose sharp stings no monkey or tiger-cat would desire to face.

The crested cassique, the largest of the family, builds his pensile nest, artificially woven of lichens, bark, fibre, and the filaments of the tillandsias, on the tallest trees close to the habitation of man; while that of the tupuba (*Cassicus ruber*), which is always suspended over the water, consists of dry grasses with a slanting opening in the side so that no rain can penetrate it. On passing under a tree which often bears hundreds of cassique nests, one cannot help stopping to admire them, as they wave to and fro, the sport of every breeze, and yet so well constructed as rarely to be injured by the severest storm. Often numbers of one species may be seen weaving their nests on one side of a tree, while numbers of another species are busy forming theirs on the opposite side of the same plant; and what is perhaps even still more wonderful that their architectural skill, though such near neighbours, the females of these contiguous colonies are never observed to quarrel.

The Baltimore oriole (*Yphantes Baltimore*), a bird closely allied to the cassiques, builds his wonderful nest on the tulip-tree, whose leaves and flowers are his chief hunting-grounds for caterpillars and beetles. When the time is come to provide a cradle for the future progeny, the male gathers the long filaments of the tillandsia or other threadlike materials, and fastens one

of them with both ends to two neighbouring branches. Soon after the female comes, inspects his work, and places another fibre across that of her companion. Thus by their alternate labours a net is formed, which soon assumes the form of a pensile nest, and as it advances towards its completion, the affection of the tender couple seems to increase. Although so strongly constructed that it will bear a good deal of rough handling without losing its form, the tissue is at the same time so loose as to allow the air to pass through its meshes; and as the parents know that the excessive heat of summer would incommode their young, they suspend their nest so as to catch the cooler breeze of the north-east, when breeding in Louisiana; while in more temperate regions, such as Pennsylvania and New York, they always give it a southern exposition, and take care to line it with wool or cotton. The movements of these ingenious little architects are uncommonly graceful, their song is sweet; they migrate in winter towards more southerly regions, such as Mexico or Brazil, and return after the vernal equinox to the United States.

The wonderful pendulous nests of the American cassiques are emulated by the labours of the African ploceidæ or weaver-birds. Most of the numerous species of this ingenious family likewise suspend their fabrics to the ends of twigs, small branches, drooping parasites, palm-leaves or reeds, and many always hang their nests over water, and at no very great height above its surface. This serves as an effectual protection against their enemies the monkeys and tree-snakes, under whose weight the slender basis of the nest, were they to attempt its capture, would infallibly give way and precipitate them into the water beneath. 'In building,' says Captain Drayson; 'the birds first commence by working some stout flags or reeds from the branch, so as to hang downwards. They then attach the upper part of the nest to the branch, so as to form the domelike roof. By degrees they complete the globular ball, still working downwards, and lastly the neck is attached to the body of the nest. Great skill is required to keep the neck even and open, and yet no machine could accomplish the work better than do these ingenious little architects. The upper part of the nest is very thick and firmly built, more than twice as thick as the neck, and the material of which it is made is far stronger. In some

instances I have seen one nest attached to another; and when this is the case, the second builder strengthens the first nest, and then attaches his own work thereto. Should by chance a hawk or monkey venture into the vicinity of a colony of these birds, it is chased and chirped at by hundreds of the little creatures, who make common cause against the intruder and quickly drive him off. During the building of the nests, the riverside is a most interesting place, as the intelligence and diligence of the birds are most remarkable.'

'If the hand,' says the author of 'Homes without Hands,' 'be carefully introduced up the neck of one of these nests, its admirable fitness for the nurture of the young birds is at once perceived. When merely viewed from the outside, the nest looks as if it would be a very unsafe cradle, and would permit the young birds to fall through the neck into the water. A section of the nest, however, shows that no habitation could be safer, and even the hand can detect the wonderfully ingenious manner in which the interior is constructed. Just where the neck is united to the ball, a kind of wall or partition is made about two inches in height, which runs completely across the ball, and effectually prevents the young birds from falling into the neck.'

Among the pensile nest-builders of India, the baya sparrow yields to none in ingenuity. These clever little birds are found in most parts of Hindostan; they have no song, and can only chirp in a monotonous manner, but the want of voice finds its compensation in the brilliancy of the plumage; for though the back and wings are brown, the head and breast are of a bright yellow, so that in the rays of a tropical sun the bayas have a splendid appearance when flying by thousands in the same grove. For they are fond of associating in large communities, and cover clumps of palmyras, acacias, and date-trees with their nests. These are formed of long grass, woven together in the shape of a bottle, and suspended, like those of the cassique and African weaver, to the end of flexible branches—for throughout the whole tropical world the same instinct has been given to guard against the same dangers. Sometimes the nest is made only for incubation, sometimes it is intended merely as an arbour in which the male sits while the female incubates

her eggs, and sometimes the nest and arbour are woven into one.

The Hindoos are very fond of these birds for their docility and sagacity; when young they teach them to fetch and carry, and when the young women resort to the public fountains, their lovers instruct the baya to pluck the tica or golden ornament from the forehead of their favourite, and bring it to their master.

Nests of the Baya Sparrow.

Generally each pair of the numerous species of weaver-birds constructs its separate nest, but the social grosbeak forms a remarkable exception to the rule; for here we find not one single pair but hundreds living under the same roof, perfectly resembling that of a thatched house, and with a projecting ridge so that it is impossible for any reptile to approach the entrances concealed below. These lead to avenues within, with nests ranged on both sides about two inches apart; and thus, though inhabitants of the same aërial city, each pair enjoys its own private dwelling. The tree usually selected for these nests is the giraffe-acacia, which derives its name from its constituting

the chief food of the camelopard; for the instinct of the birds seems to have pointed out to them that it is peculiarly adapted for the purpose, as its smooth and polished bark effectually secures them from the attack of many enemies, who, could they but ascend the trunk, would be but too happy to suck the eggs and destroy the young.

The Tailor Bird and its Nest.

The art of sewing is considered as one of the oldest inventions of man; but long before a human artist ever thought of using needle and thread, the birds had instinctively been taught the virtues of a fibre thrust through holes. Thus the Sylvia Cysticola, or fan-tailed warbler of Italy, constructs its nest among sedges and reeds, which it unites together by real stitches; and the edge of each leaf is pierced by this tailor-bird with minute holes, through which it passes threads formed of spiders' web, particularly from the silk of their egg-pouches. The tailor-birds of India are still more expert sewers, for, choosing a convenient leaf (generally one which hangs from a slender twig), they pierce a row of holes along each edge, using their beaks in the same manner that a shoemaker uses his awl. When the

holes are completed, the feathered tailor next procures his thread, which he takes care to choose of a sufficient length and solidity, and begins to pass it through the holes, drawing the sides of the leaf towards each other, so as to form a kind of pouch or purse open above. Generally a single leaf is used for the purpose, but whenever the bird cannot find one that is sufficiently large, it sews two together, or even fetches another leaf and fastens it with the fibre. Within the hollow thus formed, the bird next deposits a quantity of soft down, and having completed her nest, leaps from branch to branch to testify her happiness by a clear and merry note.

The mounds in which the tallegalla or brush-turkey deposits its eggs are in their way no less remarkable than the most ingenious nests. Like the thatched dwellings of the republican grosbeak, they are not the work of a single pair, but of a large number of birds, who have been taught by a beautiful instinct to direct their labours to a common end. Tracing a circle of considerable radius, the birds begin to travel round it, continually grasping with their large feet the leaves and grasses and dead twigs which are lying about, and flinging them inwards towards the centre. Each time that they complete their rounds, they narrow their circle, so as ultimately to form a large and rudely conical mound. The heap being accumulated, and time allowed for a sufficient heat to be engendered, the next process is to form a cavity, in which the eggs, each measuring not less than four inches in length—an enormous size in comparison to that of the bird—are deposited, not side by side, as is ordinarily the case, but planted or arranged perpendicularly, and nearly in a circle, with the larger end upwards. They are then covered up, and are hatched by the joint effects of fermentation and hot sunbeams. By adopting this process the bird does not escape any of the cares of paternity, for the male is very watchful over the eggs, being gifted with a wonderful instinct, which tells him what temperature is proper for them. Sometimes he covers them with a thick layer of leaves, and sometimes he lays them nearly bare, repeating these operations several times in a single day. After six weeks of burial, the eggs give up their chicks—not feeble but full-fledged and strong, so that at night they scrape holes for themselves, and lying down therein are covered by the old birds, and thus remain until morning.

The extraordinary strength of the newly-hatched birds is accounted for by the size of the egg, since in so large a volume it is reasonable to suppose that the young ones would be much more developed than is usually the case.

Even where architectural skill is totally wanting, and no nests are built or no leaf-mounds raised, the birds evince an admirable care for the welfare of their future progeny.

The sea-lark contents herself with laying her four eggs in a small cavity on the ground, but places them with the small ends touching each other as a centre, so as to occupy the least possible space, and thus to be more easily hatched. No mathematician could have solved the problem in a more perfect manner; and is not this instinct, after all, as wonderful as that which prompts other birds to construct the most complicated dwellings? Even the auk, who lays her single egg upon the bare edge of lofty rocks hanging over the sea, invariably selects the safest spot against wind and weather; and though numbers of birds may be breeding on the same ledge, yet no confusion ever takes place, for every mother, guided by an unerring instinct, knows her own egg, and is able to find it among hundreds.

The parental instinct of birds might be supposed to have reached its lowest ebb in the cuckoo, who never hatching her own eggs, deposits them in the nests of other and smaller birds, such as the hedge-sparrow, the titlark, or the water-wagtail; but it would be doing the parasitical intruder injustice to attribute this shifting of her own burden upon the shoulders of another to a peculiar coldness of disposition, or to a culpable neglect of duty; for as the caterpillars on which the large bird feeds do not afford sufficient nourishment for a rapid evolution of germs, the cuckoo lays but one egg every eight days, from the beginning of June to the middle of July, and it surely would be a grievous task were she obliged to incubate during the best part of the summer. But a most admirable instinct has taught her to seek a substitute for a duty she is unable to perform herself; and it is not the least wonder of this strange history, that the eggs of the cuckoo are of an unexampled smallness, so as to differ but little in size and appearance from those of the skylark and titlark, though the disparity of the bulk of the birds is very great. Thus we see that though the

young of the cuckoo miss a parent's fostering care, nothing has been left undone that might lead to their benefit.

When a breeding bird is attacked by an enemy, it exhibits either a brilliant heroism or an admirable courage. In defending their young, the large birds of prey display the same fury which agitates the wild beasts of the forest when menaced in their tenderest affections, and it is scarcely less dangerous to rob the lämmergeier of its young than to deprive the tigress of her cubs; for though this magnificent bird will never attack man when unprovoked, yet there are numerous instances on record where he has boldly engaged in mortal combat with the despoiler of his nest. Of these I shall cite but one, mentioned by Tschudi in his work on the Animal Life of the Alps.

Joseph Scherrer, a famous chamois-hunter, once climbed barefoot up a rock, with his fowlingpiece slung over his shoulder, to plunder a lämmergeier's nest. Before he reached the roost, the male bird attacked him and was shot. Scherrer reloaded his gun and continued to ascend. But now the female bird rushed upon him with inconceivable rage, buried her talons in his thighs, and endeavoured to hurl him down the precipice, wounding him at the same time with her sharp beak. His situation was most critical, for he required all his strength to keep his ground and to ward off the infuriated bird. His uncommon presence of mind saved him, however, from what seemed inevitable destruction. With one hand he directed the barrel of his gun upon the bird, and pulling the trigger with his naked toe, lodged a fatal bullet in its breast.

The adjoined facsimile of a print of the celebrated Ridinger, representing a large chamois hurled from a rock by a lämmergeier, gives us an idea of the Alpine bird's strength, and shows how truly formidable he must be, even to the most vigorous and expert huntsman, when agitated by parental rage.

Yet not only the powerful raptorial birds, but even the weakest of the class become inspired with a lionlike courage when the safety of their progeny is at stake. On the approach of an intrusive bird, though ten times bigger than himself, the male colibri will not hesitate a moment to attack the disturber of his rest; his bravery adds a tenfold increase to his powers, the rapidity of his movements confounds his enemy, and finally

puts him to flight. Proud of his victory, the little champion returns to his partner, and flaps triumphantly his gemlike wings.

The artifices employed by the partridge, the lapwing, the ringplover, the pewit, and numerous other land-birds, to blind the vigilance and divert the attention of those who may come near their little ones, are equally curious. When the sea-lark sees the enemy—man or dog—approach, it does not await their arrival but advances to meet them. Then suddenly rising with a shrill cry, as if just disturbed from its nest, it flutters along the ground as if crippled, and entices them farther and farther from its young. The dogs, expecting to catch an easy prey, follow the lame bird, which suddenly, however, flies off with lightning speed, and leaves its disappointed pursuers on the beach.

Calumny has been very busy about the ostrich, accusing it of stupidity and want of parental feeling; but it is now fully proved that no bird has a stronger affection for its offspring, or watches its nest with a greater assiduity. Contrary to the general opinion, she always broods over her eggs at night, and only leaves them during the hottest part of the day.

Her instinct in providing food for her young appears to be without parallel, and is thus noticed by Le Vaillant: 'During this day's journey I met with the nest of an ostrich, upon which the female was hatching; there were three eggs, deposited on the bare ground, lying before her, and she was sitting upon nine others, the young of which were in so advanced a state as to be ready to burst the shell.' This wonderful provision, when we consider how difficult it would be for the brood to find any other suitable food in its sterile haunts, was considered incredible when first announced as a fact by this well-known traveller; but subsequent observations have, in this instance as in many others, fully proved his veracity.

To protect her young, the ostrich has recourse to the same artifices which we admire in the plover, endeavouring to divert attention from her nest by feigning lameness or inability to fly; so that, far from being the cold-hearted and stupid creature she is frequently supposed to be, she in reality affords us a wonderful example of the power of parental affection in rousing the intelligence of an animal to higher exertions at the

D'Orbigny relates a remarkable instance of memory in an American turkey-buzzard. Relying on their inviolability, for being extremely useful as scavengers they are under the protection of the law, these disgusting birds are uncommonly bold; and during the distributions of meat to the Indians, which regularly take place every fortnight in the South American missions, they not seldom come in for their share by dint of impudence. In Concepcion de Mojos an Indian told M. d'Orbigny, who was present on one of those occasions, that he would soon have the opportunity of seeing a most notorious thief, well known by his lame leg; and the bird making his appearance soon after, completely justified his reputation. The traveller was also informed that this ill-famed *urubu* knew perfectly well the days of distribution in the different missions; and eight days later, while witnessing a similar scene at Magdalena, twenty leagues distant, he heard the Indians exclaim, and looking up, saw his lame acquaintance of Concepcion hurrying to the spot with the anxious mien of a famished traveller, afraid of coming too late for his share. The padres in both missions assured him that the vulture never failed to make his appearance at the stated time.

The parrot gives numberless proofs of intelligence; he not only imitates the voice of man, but has also a strong desire to do so, which he manifests by his attention in listening, and by the continuous efforts he makes to repeat the phrases he has

heard. He seems to impose upon himself a daily task, which even occupies him during sleep, as he speaks in his dreams. His memory is astonishing. Le Vaillant says that he heard a parrot repeat the Lord's Prayer from beginning to end in the Dutch language; and M. de la Borde told Buffon he had seen one that was fully able to perform the duty of a ship's chaplain. This intelligent bird is also susceptible of great attachment to his master, and, like the elephant, does not easily forget the insults he has received, and knows how to resent them.

The stork also has a most wonderful memory, and soon learns to understand the actions and even the language of man. Dr. Schinz, a Swiss naturalist, kept during several years a couple of tame storks, and thus had frequent opportunities of noticing their remarkable intelligence. They knew their names as well as a dog, and on being called, would immediately come to their master. During the season of the cockchafers, they followed him to pick up the beetles he shook down from the trees, and evidently invited him by their gestures to do so. They are very fond of earthworms, and when anyone took a spade in his hand, they immediately understood what was meant, and ran up to him while digging, as if well aware that they had a treat to expect.

The migratory instinct, although sometimes occurring in other classes of animals, is much more general among the birds, who, thanks to their light wings, possess the enviable privilege of enjoying the delights or avoiding the inclemencies of every climate. They do not wait till the cold becomes intolerable—they are not gradually driven away by the increasing severity of the autumnal blasts; but before necessity makes itself felt, a strange restlessness seizes them, an invincible impulse to wing their flight to distant regions. Then the storks assemble in large flocks, and though usually silent, make a loud clattering noise, as if consulting before the journey they are about to undertake; when they are actually on the point of leaving, the whole troop becomes silent, and moves at once, generally in the night, to alight in a few days in Egypt or Nubia, on the sunny banks of the abounding Nile. There they enjoy the temperate warmth of a tropical winter; but when the heat increases, their travelling instinct revives, and forces them to return to the northern lowlands, where genial spring awaits

them, with the plenty and the mild temperature they require for the rearing of their progeny.

While numerous birds leave us in autumn, others, which have brought forth their young in the Arctic regions, seek our shores at that season of the year, or pass over our heads on their way to more southern lands: for the icebound lakes, the frozen rivers, the deserted channels, and the snowclad shores of the hyperborean zone are no longer able to afford them any nourishment, and in spite of their thick downy mantle, a temperature which converts mercury into a solid body may render a change desirable. But as the days again lengthen, and the sun, rising higher and higher in the heavens, dissolves the iron bonds of winter, the dispersed legions of ducks, geese, swans, strand and sea-birds advance once more from the south to feast upon the abundance of the softened earth or of the prolific waters, and to rear their young under the grateful influence of a continuous day.

Thus the living tide ebbs and flows in everlasting succession, and as the floods of the ocean obey the behests of distant celestial bodies, thus also the migrations of the birds are ruled by immutable and eternal laws!

CHAPTER XXVII.

MAMMALIA.

Modifications in the Structure of their Limbs—Fins of the Whale, Walrus, and Seals—Wings of the Bat—The Nycteris—The Flying Squirrel—Shovels of the Mole—Limbs of the Cervine and Bovine Races—The colossal Pillars of the Elephant—The Hare—The Jumping Hare—The Kangaroo—The Sloth—Monkeys—Leaps of the Wanderoo—The Squirrels—Soles and Toes—Sole-pads of the Camel—Prehensile Tail of the American Monkeys and other Quadrupeds—Tail of the Aquatic Mammalia, of the American Ant-Bear, of the Kangaroo and Pengolin—Masticatory Organs—Teeth of the Carnivora, the Ruminantia, and the Rodents—The Baleen of the Whale—The Ant-eater's Tongue—The Stomach of the Ruminants—The Camel's Paunch—Water-pouches of the Elephant—Cheek-pouches of the Hamster—Senses of the Mammalia—The Elephant's Proboscis—Defensive and Aggressive Weapons of Mammalia—Burrows of the Prairie Dog—The Hamster's Cave—Habitations of the Beaver and the Musquash—The Mole and the Australian Duckbill—The Armadillo and the Hedgehog—The Porcupine—The Skunk—Gregarious Quadrupeds—Guards—Bird-guardians of the Rhinoceros and the African Buffalo—Friendships of Animals—The Tiger and the Dog—Attachment of Domestic Animals to Man—Parental Affection—Pouch of the Opossum and Kangaroo—Services of the Quadrupeds—Sagacity of the Dog, the Horse, the Monkey and the Elephant—Hybernation—Happiness of the Wild Quadrupeds.

THE Mammalia, the last-born of creation, exhibit the highest types of organic development, a greater harmony between the various parts of the nervous system than is found in any of the preceding classes, an increasing preponderance of the brain. Several of them—such as the Rodents or Opossums—are, no doubt, inferior to many of the birds in point of intelligence and instinct; but even the most perfect among the feathered tribes are not to be compared in this respect to the horse, the dog, the elephant, or the ape; and although civilized man delights in the song of birds, or in the beauty of their plumage, yet his connection with the domestic mammalia is far more intimate; for without the assistance of these humble companions, his own

existence on earth would be reduced to the low level of the wretched Fuegian or of the wild Indian hunter.

As the mammalia bow to the supremacy of man, thus also, with rare exceptions, all other animals are subject to their dominion: swimming, they pursue the fishes of the sea; flying and burrowing, they give chase to insects and worms; climbing and springing, running and lying in wait, by cunning or by violence, they prey upon the birds that nestle in the trees of the forest or seek concealment in the fields.

Bones of the Anterior Fin of a Whale (Balæna Mysticetus).

Although their internal parts are very similarly organised, yet so vast a difference in their mode of life necessarily required corresponding modifications in the structure of their limbs, which, though formed upon the same fundamental plan, have in every case been most beautifully adapted to answer a peculiar end.

The whales and dolphins, to whom the wide ocean has been given as a home, naturally require no fingered hand for climbing, no legs for bounding with elastic spring. A mighty horizontal tail stretching sideways into an enormous fin, and striking up and down, impels the giant body through the waters; the hind-feet, which here would not only have been useless but a positive incumbrance, are wanting; and the anterior extremities assume the form of large pectoral fins, which, besides performing the offices of oars, serve also to protect and guide the helpless young. The anatomical structure of these members, externally so totally different from the human

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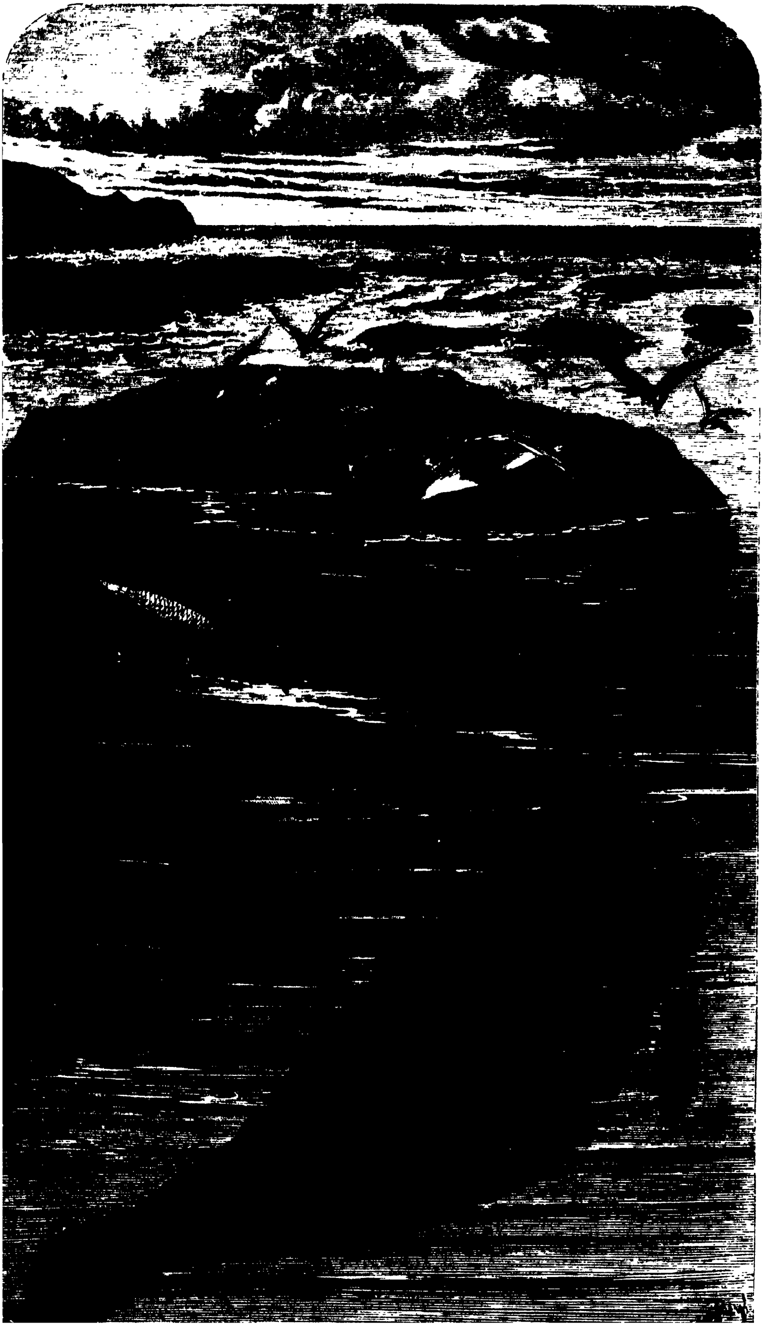
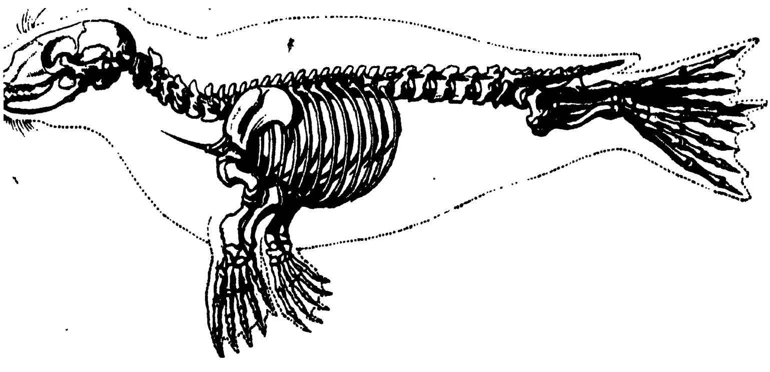


arm and hand, shows us, however, that they are both intrinsically alike—as in the anterior fin of the whale we distinctly perceive the bones which belong to our own anterior extremities. But the arm, which in all its parts is freely moveable in man, is here closely attached to the body; and the hand—which, obedient to our rational will, performs so many wonderful works—is in the whale covered with a thick skin, which prevents all individual action of the fingers, and converts the member into a simple oar, such as best suits the animal's peculiar mode of life.

The same absence of hind-legs characterises the manatees and dugongs, but here the paddles or forefins are more free in their movements, and exhibit rudiments of nails, by the aid of which



Skeleton of Seal.

these unwieldy creatures drag themselves along the shores of gulfs and estuaries, to browse on the marine algæ which constitute their food.

Hinder Extremities of Seal.

In the walrus and the large family of seals, which have been formed to inhabit both the sea and the land, the forelimbs are still more developed; and short hinder extremities, with distinct toes, joined by a swimming membrane, and well adapted both for rapidly cleaving the waters and slowly progressing on solid ground, assume the part of the receding tail.

Among the other mammalia which seek their prey in the

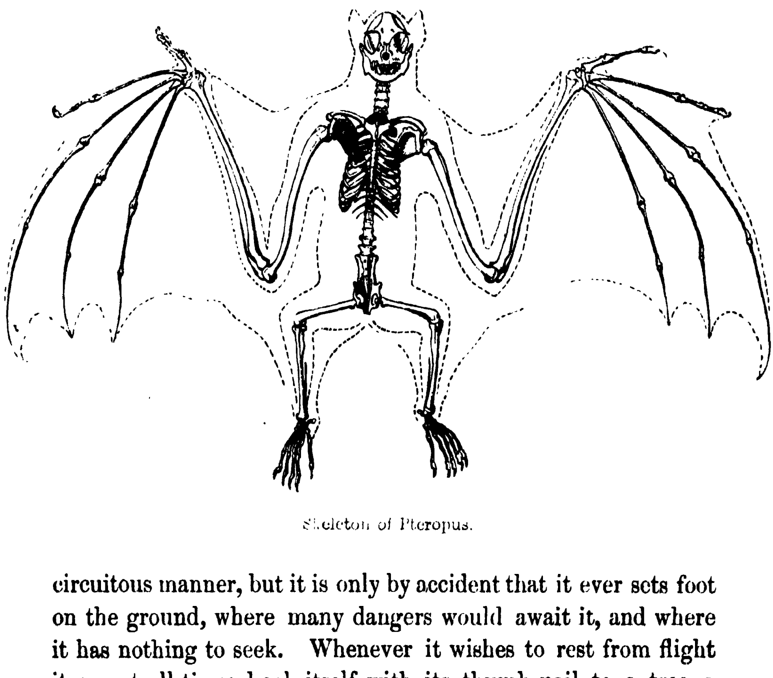
waters, we find the construction of the extremities equally well-fitted for swimming. Thus the legs of the otter are short and strong, but so loosely articulated as to turn in every direction while swimming—the feet broad, to act as paddles, and the toes connected by a complete web. Provided with such excellent oars, which are moreover assisted by the flat and broad tail and the elongated and much-flattened body, the otter is able to breast the stream for hours together—raising its head from time to time out of the water, to draw breath or to look about him.

The amphibious beaver and the extraordinary mullingong, or duck-billed platypus, whose existence as a mammalian was long a matter of doubt, likewise show by the formation of their extremities how well their peculiar wants have been provided for. In its webbed hind-feet the former possesses most excellent rudders, while the unwebbed toes of its forefeet are no less admirably adapted for seizing the branches and trunks of trees, which it uses for the construction of its huts, or on whose bark it feeds.

In the mullingong, on the contrary, we find the forefeet provided with a web, which not only unites and fills the interspaces of the long toes, but even extends beyond the extremities of the claws; while the web of the short and narrow hind-foot, terminating at the base of the claws, is far less developed. But as the mullingong is not only an aquatic but also a burrowing animal, the large web of the forefeet, which else would have been very much in the way, is loose, so as to fall back when its possessor is scratching the earth; and thus, by a most ingenious contrivance, the same organ serves equally well as an oar and as a shovel.

While in all these cases the limbs are most admirably fitted for an aquatic or amphibious life, those of the bats are no less beautifully adapted for aërial locomotion. For here the slender delicate bones of the forearm, and particularly those of all the fingers excepting the thumb, are extremly elongated, so as to serve like the frame of an umbrella for the expansion of an enormous wing or thin membrane, which reaches also to the hind-legs, and from them to the tail. It is evident that with forefeet like these, the walking or creeping movements of the bat must be exceedingly awkward, and that the strange creature is far from

being a model of grace, when with folded wings it crawls slowly along on its projecting elbows. To fly upwards from the ground is a still more difficult task, and in the large-winged species is impossible. In this case the bat is obliged to crawl up a wall or a tree, which it can easily do by means of its sharp claws, and then dropping down it expands its wings in the air. Its organization would surely have been very imperfect were it always obliged to prepare for flight in this inconvenient and



Skeleton of Pteropus.

circuitous manner, but it is only by accident that it ever sets foot on the ground, where many dangers would await it, and where it has nothing to seek. Whenever it wishes to rest from flight it can at all times hook itself with its thumb-nail to a tree, a rock, or any other rough surface; and during sleep it suspends itself by its hinder-claws with the head downwards, under the roofs of houses and churches, in caverns, ruined buildings, and similar situations, so as to be able to spread out its wings immediately, whenever it desires to do so. Its forearm is incapable of rotating like the human arm, in consequence of the union of the bones of which it is composed, and this is another admirable adaptation to its peculiar habits. Not only would the pronation and supination of the hand be wholly useless to the bats,

but at every impulse of their flight such a motion would deprive the whole limb of its resistance to the air; or it would require the constant exertion of such a degree of antagonising muscular force to prevent it, as would be incompatible with the essential structure of these organs of flight.

As we have seen in the preceding chapter, the natatorial birds have a large gland situated at the extremity of the back, with whose unctuous secretion they lubricate their feathers, and thus render them impermeable to the wet. A similar protection has also been afforded to the bats in the oily secretion of their wings, so that in damp weather the rain, which otherwise would very much impede their flight, drops from them as from a weatherproof mantle.

But it is not only by their winglike arms that the bats are admirably formed for flight—the whole structure of their body harmonises as well with their peculiar mode of life, as the long tapering shape of the seals or whales with their aquatic habits. All their bones, not merely those of the arms, are extremely thin and slight; the breastbone is provided, like that of the birds, with a keel, serving for the attachment of the powerful muscles which perform the movements of flight; the head is singularly diminutive and the neck short, so that the centre of gravity falls below the wings. In the genus Nycteris the specific weight of the body, and consequently the labour of flying, is still more diminished by the curious faculty possessed by these animals of inflating the subcutaneous tissue with air. The skin adheres to the body only at certain points; it is therefore susceptible of being raised from the surface on the back, as well as on the under-parts. These large spaces are filled with air at the will of the Nycteris, by means of large cheek-pouches, which are pierced at the bottom, and thus communicate with the subcutaneous spaces just mentioned. When the animal therefore wishes to inflate its skin, it inspires, closes the nostrils, and then, as it contracts the cavity of the chest, the air is forced through the openings in the cheek-pouches, under the skin, from whence it is prevented from returning by means of muscular contraction, and by large valves on the neck and back. By this curious mechanism, the bat has the power of so completely blowing up the spaces under the skin as to give the idea of a small balloon, with wings, a head, and feet. In Johnson's well-known tale of

'Rasselas,' we meet with a mechanician who, wishing to try a pair of artificial wings which he had invented, fell headlong into a lake a short distance from the tower whence he had first taken his adventurous flight. Had this unfortunate man been able to render his bones comparatively as light as those of the bat—had he been able to reduce the weight of his body to a tenth part, and to render, at the same time, the muscles of his arm ten times thicker and more powerful than they were, then, perhaps, he might have been more successful: or, had he studied the anatomy of the bat, he surely would have given up all idea of ever rivalling a creature of a construction so different from that of his own body!

All the European bats are insectivorous, but the large kalongs or flying-foxes of India, the Eastern Archipelago, and the tropical islands of the Pacific, chiefly live upon fruits. Certain modifications in the structure of the instruments of flight have been made to harmonise with this difference of diet. Thus the clavicle and the keel of the breastbone are more developed in the insectivorous than in the herbivorous bats, for the very obvious reason that the former are obliged to use greater exertions in the pursuit of their swift and active prey, than the latter in merely flying from place to place in search of their stationary food. The existence of a tail, for the support and extension of a broad membrane extending between the hind-legs, compared with its absence or comparative inefficiency in many of the frugivorous bats, also points out an interesting relation to the different habits of the two groups—the former structure being calculated to afford a powerful and effective rudder in guiding their rapid and varying evolutions in the pursuit of their insect food.

Besides the bats, there are several other mammalia which, although incapable of a prolonged flight, are assisted or supported in their movements by winglike expansions of the skin; and all these animals have a comparatively slender and light body, for Providence would never have committed the mistake of investing a huge bulky creature with so useless an appendage.

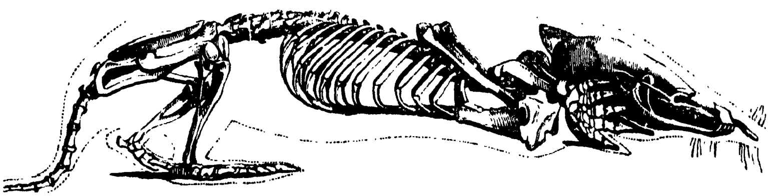
Thus, by means of a parachute-like extension of its skin between the anterior and posterior limbs on each side, and between

the posterior limbs and the tail, the flying lemur or galeopithecus of the Eastern Archipelago takes long sweeping leaps from tree to tree; and the flying-squirrels, which inhabit both the interminable forests of the North and the woods of Ceylon and India, are assisted in a similar manner by a fold of the

Flying Squirrel.

skin of the flanks, which on the extension of the limbs, front and rear, is literally expanded from foot to foot. Thus buoyed up in their descent, the spring which these elegant little creatures are enabled to make from one lofty tree to another, always directing their flight obliquely downwards, resembles the swift aërial sailing of a bird rather than the bound of a quadruped.

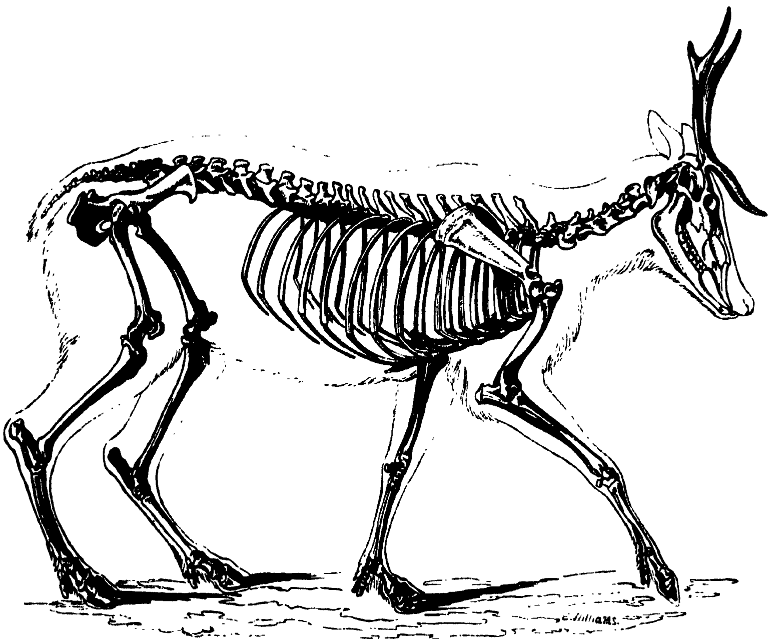
The forefeet, which in the seals and bats do service as oars and wings, are in the mole converted into powerful shovels. Situated obliquely outwards, they are excessively strong and broad, and moreover furnished with very large and stout claws; so that they are able to work their way through a favourable soil with astonishing rapidity, while the diminutive hind-feet are employed in throwing back the previously-excavated earth. The long and moveable snout, which acts in some measure as a wedge, assists the mole in pushing along through the soil: and every worm and larva it meets on its way is instantly devoured with greedy haste, for no animal is less able to endure fasting, and hence it may be inferred how great a destruction it causes



among the grubs of noxious insects. The services it thus renders are far greater than any detriment it may cause to the roots of garden-plants; and if the husbandman knew better how to distinguish his friends from his enemies, he certainly would be more anxious to protect the mole, than mercilessly to destroy it wherever he meets with it.

Though not seeking their nourishment under the earth like the mole, many other mammalians prefer a subterraneous abode, or endeavour to escape from pursuit by quickly burrowing in the earth, and in all these cases we invariably find short stout legs and powerful claws; for wherever Providence has given a creature a particular instinct, it has also taken care to provide it with the instruments that are necessary for bringing it into action. Thus armed, the armadillos burrow with such astonishing rapidity, that it is almost impossible to get at them by digging; and the African aardvarks are no less expert, for when once their muscular forefeet have penetrated into the ground, the strongest man cannot draw them back.

Long and yet muscular legs characterise those quadrupeds which are most remarkable for their agility in running. They do not tread upon the whole sole of their foot as we do, but only upon the extremity of their toes; so that the foot contributes to elongate their limbs, and enables them to make greater strides without any increase of exertion. It is to this peculiarity of gait and structure that the cervine and equine races owe both the elegant form and the unrivalled celerity of their limbs.



of the Deer.

The bovine races being of a more robust shape, and lower in proportion to their bulk, are of inferior swiftness; but these also, particularly in their wild state, unite considerable strength with a remarkable agility. The bison is so strong, that sometimes when pursued it has been known to knock down trees as thick as a man's arm in its flight, and yet so quick as to plunge even through deep snow faster than an Indian can run upon it in snow-shoes.

The limbs of the elephant are necessarily constructed more

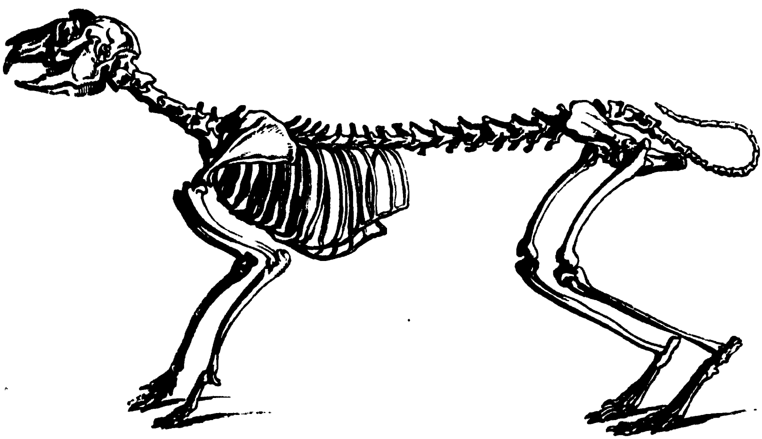
with a view to ensure strength, adequate to sustain its prodigious weight, than to permit of agile and active movements; but these massive pillars, seemingly so unwieldy and uncouth, have been made to unite strength and flexibility in a remarkable degree; so that their possessor is able to ascend and descend steep acclivities, to climb rocks, and traverse precipitous ledges, where even the surefooted mule would hardly venture. The first manœuvre of an elephant descending a bank of too acute an angle to admit of his walking down it direct (for, were he to attempt this, his huge body, soon disarranging the centre of gravity, would certainly topple over), is to kneel down close to the edge of the declivity, placing his chest to the ground; one foreleg is then cautiously passed a short way down the slope, and if there is no natural protection to afford a firm footing, he speedily forms one by stamping into the soil if moist, or kicking out a footing if dry. This point gained, the other foreleg is brought down in the same way, and performs the same work, a little in advance of the first, which is thus at liberty to move lower still. Then first one and then the second of the hind-legs is carefully drawn over the side, and the hind-feet in turn occupy the resting-places previously used and left by the forefeet. The course, however, in such precipitous ground, is not straight from top to bottom, but slopes along the face of the bank, descending till the animal gains the level below. This wonderful faculty necessarily points to a no less wonderful organisation, and the columnar legs of the elephant, which the ancients supposed to be without joints, are in reality masterpieces of mechanical contrivance.

While walking or running, the weight of the body rests upon part of the locomotive organs, while the other moves it forwards, so that the animal constantly remains in contact with the earth; but in springing the body is thrown upwards into the air, so as to alight again upon the ground, at a greater or less distance. This kind of motion is performed by the sudden extension of the hinder extremities, after they had been previously bent, and the energy and strength with which it is executed naturally depends upon the development of these parts. The feline races generally surprise their prey by suddenly darting forth upon it from concealment, like lightning from a cloud, and it requires but a single glance at the anatomical structure of their powerful

hindlegs, to show us how well they are adapted for throwing the body forwards in a tremendous bound. Thus the lion is able to make a spring of thirty feet, and the tiger leaps from a still greater distance upon the deer or the antelope that comes within his reach.

The chamois and the European steinbock or ibex are likewise remarkable for their amazing dexterity and agility in leaping, a faculty essential to their existence among the rocks and precipices of their mountain homes. Without any hesitation the chamois will spring over crevices sixteen or eighteen feet broad, and vault over walls fourteen feet high. If, when pursued by the huntsman, it is driven to an abyss, where a leap would be inevitable destruction, it pauses for a moment, and then, surmounting the fear which prompted it to fly from its persecutor, suddenly turns round upon him, and retraces the way by which it came. The huntsman may then esteem himself fortunate if he has time to throw himself flat upon the ground, or to hold fast to the rock while the chamois dashes over him.

In the hare, which springs along in successive leaps or bounds with a proverbial celerity, the hinder legs are considerably



Skeleton of the Hare

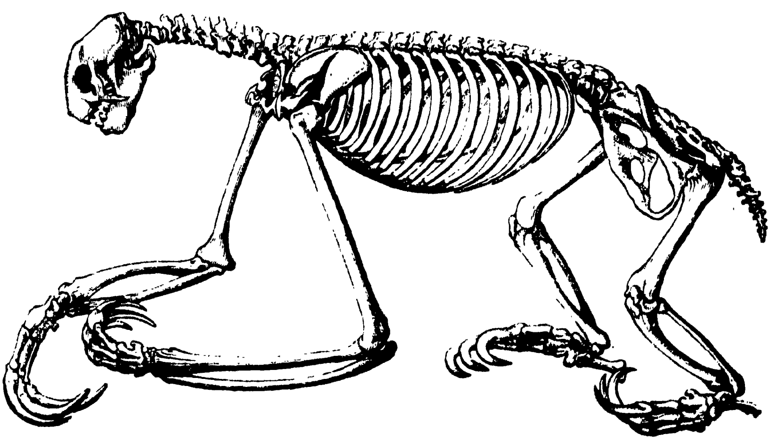
longer than the fore; and this difference is still more strongly marked in the jerboa, the jumping hare of the Cape, and the kangaroo, where the forefeet are so small as to take no part

whatever in the rapid progression of the body, which solely devolves upon the mighty posterior extremities. How well these are suited for their task is proved by the fact that the African jumping hare, which is about the size of a rabbit, will clear a space of thirty feet at one bound; that the tiny jerboa can hardly be overtaken by a horse; and

that the great kangaroo (Halmaturus giganteus), although weighing above two hundred and twenty pounds, tires even the greyhound by the rapid repetition of its prodigious springs.

While browsing on the herbage, the kangaroo is seen in a crouching position, resting on its diminutive forepaws as well as on its ponderous hinder extremities, and hopping gently along; but at the least alarm it raises itself on its hind-legs, and bounding away is soon out of sight.

What a difference in the construction of the sloth, where all the vigour of the body is concentrated in the long and sinewy



Skeleton of the Sloth.

arms, while the short hind-legs are but scantily developed! On seeing the animal, when by chance removed from its native haunts, painfully creeping along on even ground, sighing and piteously moaning, and scarcely advancing a few steps after

hours of awkward toil, it might at first sight be taken for the most wretched and ill-formed of beings—a flaw among the general beauty of the Creator's works. But this hasty judgment would soon be retracted on viewing it in the trees, the real seat of its existence, where it moves and rests and sleeps, suspended from the boughs; for then it would at once become apparent that these strong, muscular, and preposterously long forefeet are as well adapted for this peculiar mode of life as the limbs of the springing kangaroo, the burrowing mole, the swimming seal, or the flying bat, for their various spheres of action. When the sloth wanders, it first stretches out one of its forepaws as far as possible, and then the other; drawing forwards at the same time its short hind-feet, which are armed with similar strong crooked claws, and from the inverted position of their soles have a power of grasping a branch which no other mammal possesses. Thus, without any painful exertion whatever, it creeps or climbs along from branch to branch, and from tree to tree; nor does it ever, in the vast primeval forests where it dwells, require to set its foot on the ground; so that, although the worst walker among all the terrestrial quadrupeds, it has as little reason to complain of this deficiency as the whale or the dolphin of not being able to bound over the plain, or to roam through the forest. The muscular power of the sloth's forearm is so great that the animal can remain suspended for hours together without moving its position, expressing all the time its satisfaction by a kind of purring, which is surely no sign of misery.

The monkeys are also most admirable climbers but indifferent walkers, though in a less degree than the sloth. Both their hind and fore-feet are shaped as hands, generally with a thumb opposed to the other fingers and toes in the feet as well as in the hands, by which peculiarity they are enabled to grasp objects both with their anterior and their posterior extremities. The arms are generally longer and stronger than the legs, and the body slender and comparatively light—a structure which, though ill-suited for pedestrian exercise, is evidently in perfect unison with the mode of life of these arboreal creatures, and enables them to bound with such elastic energy through the green canopy of the woods.

'When the Ceylonese wanderoos are disturbed,' says Sir

Emerson Tennent, 'their leaps are prodigious; but generally speaking, their progress is made not so much by leaping as by swinging from branch to branch, using their powerful arms alternately; and when baffled by distance, flinging themselves obliquely, so as to catch the lower boughs of an opposite tree, the momentum acquired by their descent being sufficient to cause a rebound of the branch that carries them upwards again, till they can grasp a higher and more distant one, and thus continue their headlong flight. In these perilous achievements, wonder is excited less by the surprising agility of these little creatures—frequently encumbered as they are by their young, which cling to them in their career—than by the quickness of their eye, and the unerring accuracy with which they seem almost to calculate the angle at which a descent will enable them to cover a given distance, and the recoil to attain a higher altitude.'

The squirrels, which in the forests of the temperate and frigid zones perform the part of the monkeys in the tropical woods, are likewise most admirable climbers. They have no long arm, it is true, no hands to seize the branches with forcible grasp, and the trace of an anterior thumb, armed with a nail, is the only point of resemblance to remind one of the simiæ of the equatorial regions; but with equal agility they tread the mazes of their arboreal paths, and it is equally difficult to shoot them when in motion. They have been seen when hard-pressed, and when the distance to the next tree has been beyond their most extravagant leaps, to throw themselves off, spreading abroad their limbs, so as to make their body as parachute-like as possible to break their fall; and on reaching the ground without harm, bound along for the few intervening paces, and ascend the tree with a celerity almost too quick for the eye to follow.

Thus the Almighty has created mammalia of the most dissimilar forms for an arboreal life, and yet, however different their organization, none can be said to surpass the other, for each of them is perfect in its kind. In the perennial foliage of the tropical forests the sloth finds an abundant and never-failing supply of food, so that he requires no great agility, and can well afford to miss the faculty of leaping from tree to tree. But the fruits of the forest are more thinly scattered—they

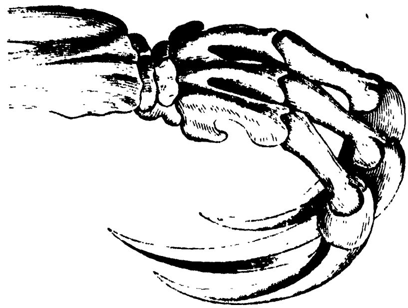
ripen far apart and at different times; and thus the monkeys and squirrels absolutely required a greater celerity of motion, to be able to seek at a greater distance the food which the exhausted neighbourhood no longer afforded. In this instance, as throughout the whole of the animal kingdom, we therefore find the mode of life and the organization, the want and the means of supplying it, in perfect unison. The trees correspond to their fourfooted inhabitants, and these again to the trees on which they dwell; and the climbing sloth, the leaping monkey, and the nimble squirrel, however dissimilar in form, prove all alike that one grand harmonious idea pervades the woods and every creature existing beneath their shades.

With regard to the formation of the soles and toes, we likewise find in every case the same beautiful adaptation of means to end. In all the burrowing mammals the toes, as we have already observed, are provided with strong claws, which render them good service in scratching away the earth through which they dig their way. These useful implements of peaceful labour serve them also as powerful means of defence, while the feline races use their claws as offensive weapons, formidable to every creature that comes within their reach. To keep their sharpness unimpaired, and to prevent them at the same time from impeding the animal's walk, the terminal phalanx on which the claw is fixed is capable of being retracted when in a state of rest by means of elastic ligaments; while a strong flexing muscle, subservient to the will, is ever ready to thrust it out, and consequently to protrude the talon whenever its services are required.

This weapon, thus beautifully constructed for action and repose, with which our tiny domestic cat is capable of inflicting painful wounds, acquires in the larger felines so prodigious a force that the tiger will draw furrows five inches deep through the flesh of his victim, and the lion tear open with one single stroke the breast of an antelope.

The claws are likewise of great assistance in climbing. In the sloth, where they are very long, powerful, and recurved, they serve as hooks for suspending the animal from the branches; and in the squirrel, where they are smaller and extremely sharp, they penetrate into the bark of the trees, and thus secure the nimble creature from falling as he bounds along. The monkey,

provided with four grasping hands, and frequently also with a prehensile tail, did not require this accessory aid—flat nails sufficed to give the soft finger-ends the solid support they needed; and it is only in the American squirrel-monkeys, where the fore-feet are not hands (as in the other monkeys) but mere paws, that the fingers are armed with claws. In the dog, the hare, and several other animals, where the claws are used neither for



Hand of the Sloth.

burrowing nor climbing, nor for defensive or offensive warfare, they afford the advantage of giving the feet a greater steadiness while running; and in the jerboa, which required a particular contrivance to be able safely to execute its enormous leap, we find, besides the strong claw with which the three toes of the hind-feet are provided, a very small spur or back-toe with its corresponding claw, which naturally breaks the impetus of the fall.

The cloven condition of the hoof in the cervine and bovine races is evidently designed to impart lightness and elasticity to the spring; and in order to give full effect to such an arrangement, many species are provided with a special glandular sebaceous follicle between the toes, whose office is to furnish a lubricating secretion, calculated to prevent injury from friction of the digits one against the other. In the stag and antelope the hoofs are compact and vertical, to heighten the firmness of the spring when bounding through weedy thickets and on grassy moors; but in the reindeer the joints of the tarsal bone admit of lateral expansion, and the front hoofs curve upwards, while the two secondary ones behind (which are but slightly developed in the fallow-deer and others of the same family) are

prolonged vertically, till in certain positions they are capable of being applied to the ground; thus adding to the circumference and sustaining power of the foot, a structure which, by giving the animal a broader base to stand upon, prevents it from sinking too deeply into the snow, and thus greatly facilitates its movements. A formation precisely analogous in the buffalo seems to point to a corresponding design. The ox, whose life is spent on firm ground, has the bones of the foot so constructed as to afford the most solid support to an animal of its great weight; but in the buffalo, which delights in the morasses on the margin of pools and rivers, the foot has a construction similar to that of the reindeer. The toes spread apart widely on touching the ground; the hoofs are flattened and broad, with the extremities turned upwards; and the false hoofs behind descend, till they make a clattering sound as the animal walks.

The cloven form of the hoof is attended with the additional advantage of aiding the voluntary elevation of the foot when it has sunk deeply into soft ground. 'We may observe,' says Sir Charles Bell, 'how much more easily the cow withdraws her foot from the yielding margin of a river than the horse. The round and concave form of the horse's foot is attended with a vacuum or suction as it is withdrawn, while the split and conical-shaped hoof expands in sinking, and is easily extricated.'

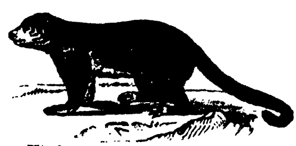
The elastic sole-pads with which several of the ruminants are furnished afford likewise a most striking example of the adaptation of structure to the exigencies of the creature. It is this formation which enables the chamois to execute its prodigious leaps on a rocky ground, which would dash the hard hoof of the horse to pieces, and permits the camel to travel with peculiar ease and security over dry, stony, and sandy regions.

In this animal the digits are more or less completely embedded in a broad elastic cushion, which extends, for a considerable distance laterally, on either side of the foot, binding and fixing the toes immoveably together; while the hoofs are merely represented by two rudimentary nails, situated on the dorsal surface of the tip of each toe.

The llamas are similarly provided with a sole-pad, but here it is double and narrow, each division being limited to one side

of the cloven foot; while the nails, instead of being weak, are very powerfully developed and strongly curved. The easy separation of the toes, combined with the modifications of the pad and hoof here referred to, is of manifest utility to an animal whose life is destined to be spent, unlike that of his more valued congener, on the rugged slopes and precipices of a mountainous district.

The tail of the mammalians likewise undergoes many modifications of form, according to the services it is required to render. In many quadrupeds it is of stunted proportions, or even entirely wanting, as in the anthropomorphous apes—the chimpanzee, the gorilla, the orang, and the gibbons—in others it serves as an ornament, or merely to drive away or punish troublesome insects; but in many cases its functions are of a much more important nature, or even completely indispensable. Thus the powerful prehensile tail of many of the American monkeys is fully entitled to be called a fifth hand, which eminently contributes to the celerity of their movements, and is hardly less wonderful in its structure than the proboscis of the elephant. Covered with short hair, and completely bare underneath towards the end, this admirable organ rolls round the boughs as though it were a supple finger, and is at the same time so muscular that the monkey frequently swings with it from a branch, like the pendulum of a clock. Scarce has he grasped a bough with his long arms, when, immediately coiling his fifth hand round the branch, he springs on to the next, and, secure from a fall, hurries so rapidly through the crowns of the highest trees that the sportsman's ball has scarcely time to reach him in his flight. When the miriki, the largest of the Brazilian monkeys, sitting or stretched out at full length, suns himself on a high branch, his tail suffices to support him in his aërial resting-place; and even when mortally wounded, he remains a long time suspended by it, until, life being quite extinct, his heavy body, breaking many a bough as it descends, falls with a loud crash to the ground.



Kinkajou (Cercoleptes caudivolvulus).

The coandu (*Cercoleptes coandu*), a kind of American porcupine, and the kinkajou or potto, a mild inoffensive plantigrade,

both leading an arboreal life in the forests of South America, are likewise provided with long prehensile tails, which afford them great assistance in wandering from branch to branch.

Among the mammals of the Old World we find the possession of a prehensile tail confined to the phalangers, a singular genus of marsupial animals, peculiar to Australia and the adjacent isles. These creatures lead an indolent retired life in the forests, and feed partly upon the fruits of trees, partly upon the insects they manage to catch during their nocturnal rambles.

The tail, which in all these cases renders such essential services in climbing, is so made as to be of great assistance to the kangaroos in the performance of their enormous leaps. Extremely thick and muscular at the base, and gradually tapering, they rest upon it when assuming an erect or sitting posture, and its powerful action when springing jerks their body into the air with a force hardly inferior to that of their limbs. If the caudal appendage of the American monkeys deserves the name of a fifth hand, the tail of the kangaroo may thus well be called a third or additional hind-leg.

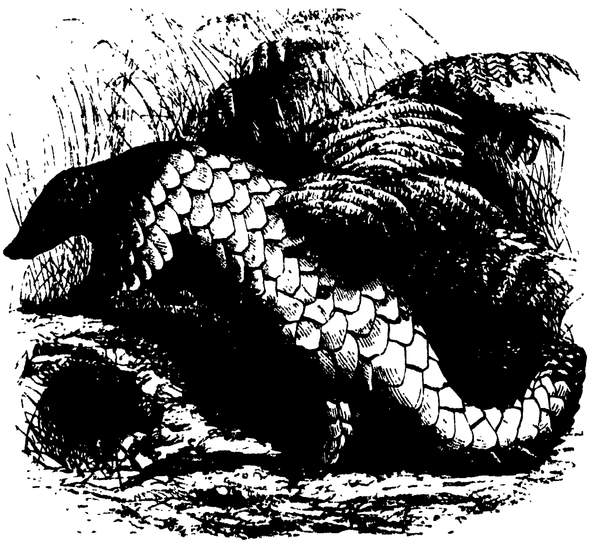
In the cetaceans the tail is of still greater importance, as here it is the chief organ of locomotion. The two horizontal fins which terminate the tail of the Greenland whale attain a width of twenty-four feet, and cover a space of two hundred square feet, and these extraordinary dimensions may serve to give an idea of the extraordinary muscular power requisite to set them in motion.

Among the other mammalia leading a semi-aquatic or amphibious life, the tail is likewise a highly important locomotive organ. Thus the otter, the duck-billed platypus, the beaver, are indebted to their long and powerful caudal appendages for a great part of their velocity in swimming; and although the hind-legs of the seals chiefly impel them through the water, they also derive considerable assistance from their tail.

The long-tailed manis, a native of Africa, makes use of this organ, which is more than twice as long as the body, and entirely covered with scales, as a covering or a shield for its head, neck, and back.

The East Indian pengolin derives great assistance from the tail in reconnoitring, resting upon it and its hind-legs, and

holding itself nearly erect to command a view of its object. The strength of this appendage, which likewise serves to secure the rolled-up animal in a powerful fold, will be perceived from the accompanying illustration, which shows it to be equal in length



to all the rest of the body, whilst the vertebræ which compose it are stronger by far than those of the back.

A perfect forest-vagabond, the great ant-eater has no den to retire to, nor any fixed abode; but his immense bushy tail renders all other shelter unnecessary, as it is long enough to cover his whole body. Serving him as a tent during the night, or as a waterproof mantle against the heavy rains of the wet season, he might boast, with still greater justice than Diogenes, of carrying all he requires about him. The tail is very differently constructed in the smaller American ant-eaters, who, leading an arboreal life, seek their prey among the species of ants that build their nests in the trees; for, like that of the monkeys of their native forests, it is long, short-haired, and prehensile.

The skin of the mammalians is no less admirably adapted to the peculiarities of their way of life than the various organs we have hitherto noticed. Thus, in the armadillos, pengolins,

and manides, who have no other means of defence, it is covered with a complete coat-of-mail, formed of transverse shelly zones or of large imbricated scales, while in the porcupine and hedgehog we find it bristling for a similar purpose with long sharp quills or spines. How different the smooth oily skin of the cetaceans, who evidently required neither bristles nor scales to protect them, and who cleave the waters all the more readily from the slippery nature of their naked integuments!

By far the greater number of the mammalians are more or less thickly covered with hair, an excellent defence against the inclemencies of the weather. A visit to a furrier's stores suffices to show the variety, softness, and beauty of these hairy coverings, at whose sight we might almost be tempted to complain of Nature's stepmotherly neglect of man, to whom no such mantle has been given.

But when we reflect that his manual skill, guided by a superior reason, gives him every means of making up for this deficiency, and that the necessity of providing himself with clothing is, in reality, one of the chief promoters of civilization, through the stimulus it gives to his industry and his inventive genius, we find that we have as little reason to envy the fur-clothed quadruped as the naked tropical savage, who, rendered almost independent of raiment or exertion by the genial mildness of his skies, scarcely rises above the level of the brutes with whom he disputes the empire of the primeval forest or the boundless savannah.

The masticatory organs of the mammalia exhibit as great a variety of structure as the food on which they live. Instead of pursuing the larger fishes, the whales, the giants of organic creation, are satisfied with game of the humblest description—crustaceans, pteropods, medusæ. Fancy how many millions of these tiny worms must be required to satisfy the wants of a colossus, whose heart at every beat sends whole tons of blood in powerful streams through arteries thicker than the body of a man! Rows of sharp teeth would evidently have been unable to perform the task, and thus we see their place supplied by plates of whalebone or baleen, fixed in the upper jaw and ranged side by side, so as to resemble a frame of saws in a saw-mill. Their interior edges are covered with fringes of hair, and from the palate are suspended many other small laminæ of the

thickness of a quill, a few inches long, and likewise terminating in a fringe; so that the whole roof of the vast mouth resembles a shaggy fur, under which lies the soft and spongy tongue, a monstrous mass often ten feet broad and eighteen feet long. Thus when the whale, after having skimmed with open mouth the surface of the ocean, closes the wide gates of his prodigious jaws, his tiny prey remains entangled by thousands and tens of thousands in a fringy thicket, where it is crushed and bruised by the tongue.

To satisfy a giant's appetite, this admirable apparatus required to be constructed on a gigantic scale; hence the enormous dimensions of the cavity of the mouth, and the seemingly disproportionate size of the head, which attains about a third part of the length of the whole body, and forms a case or box well-fitted for the reception of a straining or filtering mechanism, suited to the wants of a leviathan.

The mouth of the great ant-eater is no less wonderfully organized for the seizure and swallowing of minute insects, which paws, however sharply armed or however active in their movements, could never have captured in sufficient numbers; and as the bulky jaws of the whale cease to appear uncouth when we come to consider their uses, thus also the snoutlike elongation of the ant-eater's diminutive head no longer seems preposterous when once we know that this singular form is in exact accordance with the strange animal's mode of life. Here no spacious cavity was required for the reception of two rows of powerful teeth or of a large filtering apparatus, but a mere furrow for a long and extensile tongue, which renders all other instruments for seizing its prey superfluous—as we find on following the animal into the Brazilian savannahs, where the cities of the white-ants are dispersed in such vast numbers. Approaching one of these wonderful structures, the ant-eater strikes a hole through its wall of clay with his powerful claws; and as the ants issue forth by thousands to resent the attack, stretches out his tongue for their reception. Their legions, eager for revenge, immediately

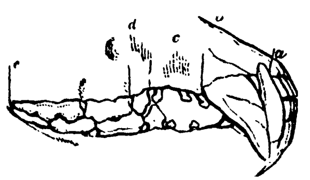
Head of the Ant-Eater.

rush upon it, and, vainly endeavouring to pierce its thick skin with their mandibles, remain sticking in the glutinous liquid with which it is lubricated from two very large glands situated below its root. When sufficiently charged with prey, the ant-eater suddenly withdraws his tongue, and swallows the poor victims of an impotent fury.

The duck-billed platypus has likewise a singular toothless mouth, which very much resembles the flat and sensitive bill of a lamellirostral bird; but this strange anomaly of form and structure entirely harmonises with the animal's food, as it subsists on aquatic insects, larvæ, molluscs, and other small invertebrates, which conceal themselves in the mud and banks of rivers, where its flattened beak well knows how to find them.

The want of teeth, or the possession of mere dental rudiments, is, however, confined but to a small number of the mammalia, for these organs are as necessary to the carnivora in tearing their prey as to the herbivorous quadrupeds in chewing, grinding, or gnawing their vegetable food; and so perfectly are they in every case adapted to the peculiar wants of their possessor, that a naturalist need only view the teeth of a quadruped to know at once upon what it feeds.

Thus in all the carnivora we find the incisor teeth only moderately developed, while the canine teeth are large, strong, and pointed, well-formed for firmly seizing and planting themselves deeply into the flesh of their victims. The molar teeth situated behind these formidable instruments of destruction are of three



Dentition of Bear

incisors. *b* laniary or cani teeth. *c* false molars. *d* sectorial molar or carnassial. *e* tuberculate or true molars.

immediately follow the canines (false molars) being more or less pointed; the next, or the carnassial tooth, being specially adapted for dividing and lacerating animal muscle by the sharp edge of its summit, while the last or hindmost are more or less rounded or tuberculated.

The proportions which these different classes of molar teeth bear to each other in degree and development, accord with the relative carnivorous propensity of the different families. Thus in the cats the canine teeth are preeminently strong, long, and

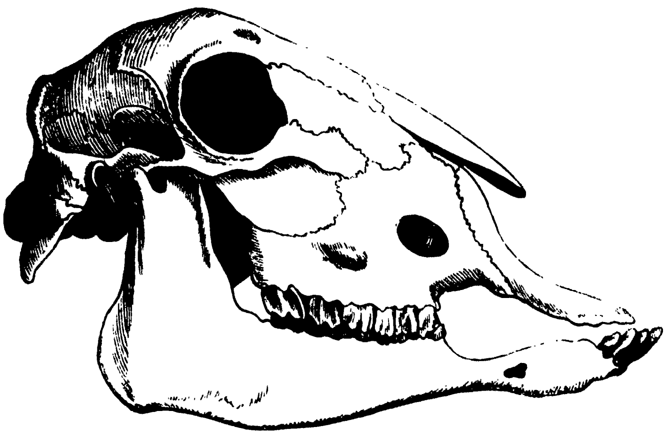
sharp, and are evidently adapted for seizing and holding their prey, and afterwards tearing in pieces the flesh and other soft parts of the animals. The conical and very slightly-curved form of these teeth, united with their sharpness and strength, is the best that can be imagined for effecting this object. The

cheek-teeth have for the most part only cutting edges, and those of the lower jaw shut within the upper, passing them so closely as to form an accurate instrument either for shearing off pieces from the flesh, or for subdividing the portions which have been torn by the canine teeth. On each of them are sharp triangular processes, which greatly facilitate the entrance of the tooth into the flesh. The range of these teeth is short, as is also the whole jaw, by which great power is gained in this particular direction. The articulation of the lower jaw is also circumscribed to a perpendicular motion, the only one which the structure of the teeth would permit; and the masticatory muscles are of enormous size and strength, particularly in the hyæna, to enable these ignoble violators of the grave to crush the bone and cartilages which form a considerable part of their bill-of-fare.

The animals of the bear tribe on the other hand, whose diet is chiefly of a vegetable nature, have an elongated jaw, canine teeth very large and strong, yet less so than in the cats, and molar teeth the surfaces of which instead of being raised into cutting edges are depressed, tuberculated, and require a certain degree of lateral motion in the jaw to bring them into action.

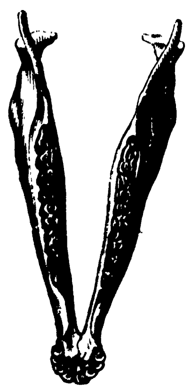
In the seals a very different structure of the teeth is observed. The canines are not particularly large and prominent, as there are no hard substances to be cut or broken, and the molar

The ruminants, who principally live on green leaves or tender shoots, naturally required a very different dentition from that



of the rodents, who have been specially appointed to devour the hardest substances, generally living upon the wood and bark of trees, as well as upon nuts and other shelled fruits. Here the lower jaw only is provided with six shovel-formed incisors, projecting almost horizontally, and pressing against the upper jaw,

Base of the Cranium of the Sheep.



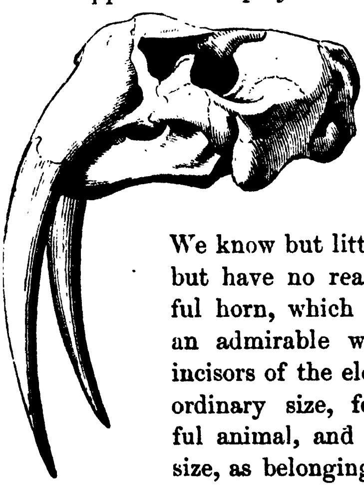
Lower Jaw of the Sheep.

which in nearly all cases is destitute of incisor teeth; their place being supplied by a kind of callous pad, a formation exceedingly

well adapted for plucking or nibbling the herbage. The canines are inconstant, and the molars, usually six on each side of both jaws, have flattened crowns surmounted by two double and irregularly crescentic folds of enamel, formed for affording the greatest possible extent of triturating surface. The lower jaw of the ruminants is not so broad as the upper one (as we see in the accompanying illustration), so that the surfaces of the upper molars project on both sides beyond those of the corresponding inferior rows; but both have been made to cover each other by the alternating lateral movements of the lower jaw to the right or to the left, a motion as admirably calculated for assisting the grinding or triturating process, as the hingelike and vertical motion of the lower jaw of the carnivora for shearing or cutting.

Several mammals are distinguished by the enormous develop ment of their canine teeth. Thus in the walrus they constitute formidable weapons of defence, and no less useful levers with which the unwieldy animal raises his huge body upon the ice-blocks and precipitous shores where he loves to bask in the sun.

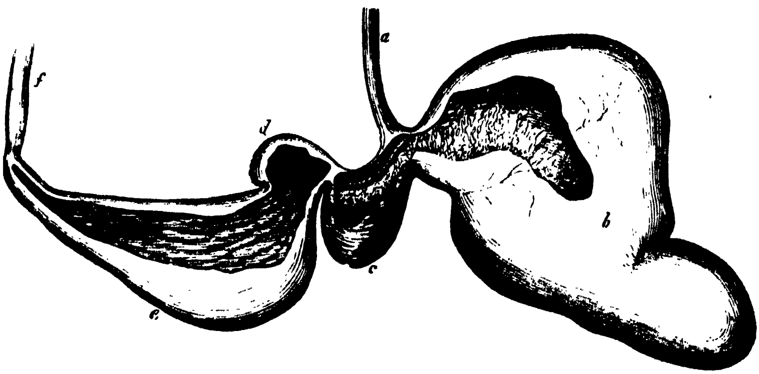
The long curved and sharp tusks of the wild-boar are capable of inflicting the most severe and painful wounds, and serve likewise for the digging-up of roots. In the narwhal only one of the upper canines projects in the shape of a formidable horn, while the other remains in a rudimentary condition. This horn, which is harder and whiter than ivory, is from six to ten feet long, spirally striated throughout its whole length, and tapering to a point. We know but little of the habits of the narwhal, but have no reason to doubt that this powerful horn, which is restricted to the males, is an admirable weapon of defence. The upper incisors of the elephant, developed to an extraordinary size, form the tusks of this wonderful animal, and not only surpass other teeth in size, as belonging to a quadruped so enormous, but are the largest of all teeth in proportion to the size of the body. Their possessor uses them for ploughing up the earth in quest of nutritious roots, or as a protection



Tusks of Walrus.

for his trunk, which when menaced he retracts between them, employing them at the same time to repel an aggressor. Thus in every deviation from the ordinary forms of dentition, we find that the attainment of some useful purpose was in view.

An examination of the digestive organs of the several orders of the mammalia, shows that in every case they are no less beautifully adapted to the peculiar food of the animal than the construction of the dental apparatus. The carnivora feeding on aliment which requires but little elaboration to convert it into nourishment, the whole process of digestion appears to be as rapid as possible, the stomach is simple and almost straight, the intestines short; and without any structure to retard the passage of the food. The ruminants, on the contrary, living on crude vegetable matters, containing but a small quantity of nutritious particles in proportion to their bulk, required a far more complicated alimentary canal for the elaboration of their food.



Composite Stomach of the Sheep.

a œsophagus. *f* duodenum.

Here, therefore, the stomach consists not of one but of four distinct cavities. The first compartment, or *paunch* (*b*), is the largest of the four stomachs, and in the typical species, such as the sheep or ox, its internal surface is densely beset with prominent and pedunculated villosities. The second stomachal viscus, or the *reticulum* (*c*), is of much smaller dimensions than the paunch, and forms a kind of *cul-de-sac* between it and the third cavity. It is distinguished internally by the presence of a multitude of polygonal cells, and from this circumstance has been vulgarly denominated the *honeycomb bag*.

The third stomach, commonly called the *psalterium* or *manyplies* (*d*), owes its name to the remarkable folding of its internal lining, the duplicatures of which resemble the leaves of a book.

The fourth stomach, technically termed the *reed* or *abomasus* (*e*), secretes the gastric juice, and is thus analogous to the simple stomach of the non-ruminating quadrupeds.

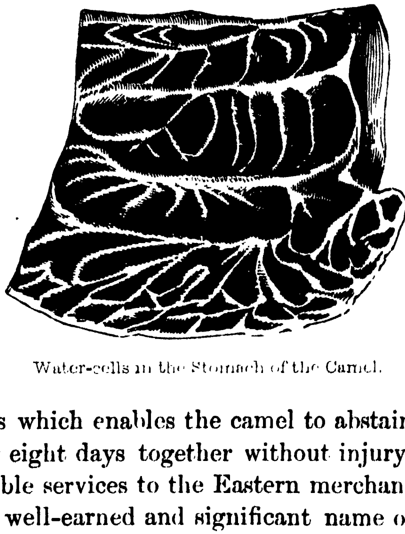
The three first stomachs communicate directly with the œsophagus by an elongated channel or groove, whose margins when distended open into the paunch and reticulum, but otherwise form a tube leading along the superior part of the reticulum to the psalterium, which in its turn communicates with the fourth stomach.

The food, coarsely divided by a first mastication, accumulates in the paunch, where it undergoes a prolonged maceration. This process is continued in the second stomach, whose contractions force it back again into the mouth; and it is only after having been chewed a second time, or ruminated, that it penetrates into the *manyplies*, and thence into the fourth stomach, which is the real seat of digestion. At first sight it seems so astonishing that the aliments should thus enter the first or the third stomach, according as they are swallowed for the first or the second time, that one might be inclined to attribute the phenomenon to a kind of intelligent selection possessed by the openings of the various paunches; but the anatomical structure of the parts explains the mystery in a far more simple and satisfactory manner. When the animal swallows coarse and bulky aliments, such as those which form its usual food, the bolus, on arriving at the point where the œsophagus begins to form the muscular channel above mentioned, *mechanically* distends the lips of the groove, and drops at once into the paunch. But when the animal swallows smaller quantities of semifluid aliments, such as those which have undergone the process of rumination, their pressure does not suffice to open the margins of the œsophageal groove, which consequently, retaining the form of a tube, conveys them at once into the third stomach.

The structure of the intestines of the ruminants corresponds with the complex arrangement of the stomach, for they are exceedingly long (in the ram twenty-eight times the length of the body), very large, and tucked up into folds and sacks throughout

their whole length. Thus in the digestive organs of the ruminants everything is most beautifully arranged for the thorough comminution and maceration of the food, and for the greatest possible retardation of its passage through the body, as well as for an immense extent of absorbing surface for the extraction of every particle of the nutritious matter it contains.

In the camel the organization of the paunch differs very materially from that of the ordinary ruminant, as its internal surface is subdivided into numerous small pouches, specially fitted for the reception and retention of water. The apertures of these cells, which have sometimes a depth and width of three inches, are narrow, and closed by strong muscular sphincters, so as to form little cisterns capable of guarding their contents for a lengthened period. It is this apparatus which enables the camel to abstain from drinking for seven or eight days together without injury, and to render those invaluable services to the Eastern merchant which have procured it the well-earned and significant name of the 'ship of the desert.' Had its stomach been differently formed, it is highly probable that the caravan-trade of North Africa and Syria, upon which the prosperity of a not inconsiderable portion of the human race depends, could never have existed. Thus the structure of the camel's stomach has not only a reference to the animal's individual wants, but also to those of man who uses its services; and surely this harmony between the various actors on the stage of desert-life must convince every unprejudiced truth-seeker that it is founded upon a grand and uniform plan, in which nothing has been left to chance, but every detail poised and arranged by Divine Wisdom!

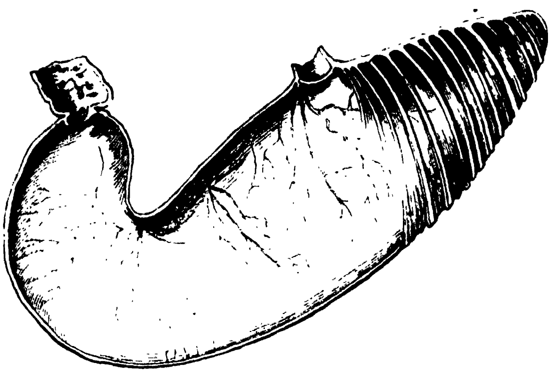


Water-cells in the Stomach of the Camel.

The camel is not only provided with water for his long desert-voyages, but also with liberal stores of fat, which are chiefly accumulated in the hump, so that this prominence, which

gives it so deformed an appearance, is in reality of the highest utility; for should food be scarce—and this is almost always the case while journeying through the desert—internal absorption makes up for the deficiency, and enables the camel to brave for some time longer the fatigues of the naked waste.

The camelides of the New World (the llamas) have a stomach similarly formed to that of the dromedary of the East, though the pouches are more feebly indicated; and the left end of that of the elephant is likewise adapted by several wide folds of lining-membrane to serve as a receiver of water. This division is of sufficient dimensions to contain ten gallons, and by means of a valve formed by the fold nearest the orifice can be shut off from the chamber devoted to the process of digestion. By this arrangement, which surely must be regarded as more than a



common coincidence, the elephant, like the camel and the llama, is enabled to traverse arid regions in the service of man.

The structure of the tongue undergoes considerable modifications according to the habits and kind of aliment of the various mammalia.

The way in which the great ant-eater uses his long and extensile lingual organ to entrap his multitudinous prey has already been noticed; but all the other quadrupeds that feed on ants, such as the Asiatic manides, the American armadillos, the Australian echidna, and the African aardvark, are similarly equipped. Thus in the four quarters of the globe we find the same peculiar formation of the tongue corresponding to an an-

alogous food; and as a considerable adhesiveness of this organ was absolutely indispensable for the securing of the prey, the secretion of a glutinous mucus destined to cover its surface has in every case been amply provided for. Thus two enormous glands are situated below the retractor muscles of the echidna's tongue, and the base of that of the pengolin is surrounded by a gland almost as long as the neck. This wonderful uniformity of structure in animals not only separated from each other by such vast tracts of sea and land, but belonging to different orders and only resembling each other in their food, must surely convince every one that they all proceed from the same Master Hand!

The graceful giraffe is likewise provided with a very long extensile tongue, but for a very different purpose, as it is used to grasp and hook down the branches of the prickly acacia or camel's-thorn, which constitute the animal's chief food. The better to lay hold of the tender shoots, the surface of this prehensile organ is as rough as that of a rasp, while a glutinous covering, like that of the ant-eater's tongue, would, moreover, have been a great hindrance to the mastication of vegetable food. Thus, wherever we look throughout the domains of Nature, we find instances of an admirable prevision extending to the minutest details, while there is not a single work of the human hand so perfect but that a sharp critic's eye may not discover numerous faults in its structure or conception!

In the phyllostomas, a tropical genus of bats, the tongue presents a peculiarity which is worthy of being particularly noted. It consists of a number of wartlike elevations, so arranged as to form a complete circular suctorial disk when they are brought into contact at their sides, which is done by means of a set of muscular fibres having a tendon attached to each of the warts. By means of this curious sucker these bats are enabled to suck the blood of animals and the juice of succulent fruits, their little sharp teeth having first made a slight incision in the skin or rind they have selected for their operations.

In some other tropical bats the horny tip of the long and extensile tongue is provided with barbed bristles, probably for the purpose of extracting the insects on which they feed out of otherwise inaccessible crevices.

While grazing, the rough tongue of the ruminants presses the

grass against the horny pad in the front part of the upper jaw, upon which the incisors of the under-jaw perform their part; the sharp tongue of the felidæ is furnished with rough horny papillæ directed backwards (these serve a very important purpose in enabling the animal to scrape off the minute particles of flesh adhering to the bones of its prey); and, finally, the enormous soft tongue of the Greenland whale fulfils most admirably the office of crushing the numberless crustaceans or pteropods that remain entangled in the fringes of the baleen.

The tongue of the mammalians is generally endowed with a wonderful delicacy of feeling. This enables it to detect any extraneous matter—a piece of bone or stone—that may have been mixed with the food, and thus it resembles a trusty door-keeper, whose watchful attention prevents any unwelcome or dangerous visitor from entering the mansion confided to his care.

Several of the mammalia have received a most useful gift in a pair of large cheek-pouches, serving as provisional storerooms. The monkeys of the New World, luxuriating in the exuberant plenty of the boundless primeval forest, do not possess them; but they are frequent among the African monkeys—an organization which evidently indicates a home where fruit is less abundant or more thinly scattered, and advantage must be taken of a favourable opportunity for securing the supply of a future repast.

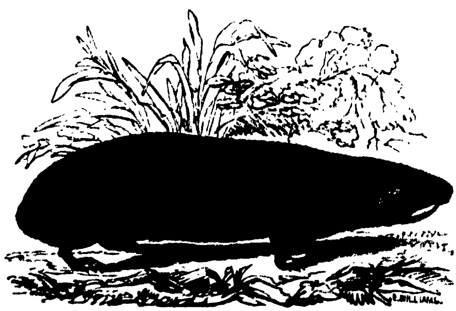
The cheek-pouches of the hamster are a great convenience to this destructive animal for carrying home its winter-provisions. They form two enormous sacks, extending from the cheeks to the shoulders, between the skin and the muscles of the neck, and when filled give the head a monstrously swollen appearance. They will contain each about a thousand grains of wheat or rye, and the hamster has merely to draw the ears of corn through his mouth to fill them, while they can be emptied with equal facility by pressing them with the forepaws.

The senses of the mammalia are developed in very different degrees, but everywhere in perfect accordance with their individual wants. Thus the carnivora, who are generally destined to live upon a cautious, vigilant, and active prey, possess a very keen sight, and even more so by night than by day; their power of hearing is delicate, while they also smell their victims with incredible acuteness.

To balance these advantages of attack, the stags, the antelopes, the bisons, and other ruminants are equally well equipped for defensive warfare. Their eyes are placed at the side of the head, so that their range of vision is greatly extended. The ears also are placed far back, and are very moveable, so that they can be turned to catch sounds in any direction, and their sense of smell enables them to detect the lurking enemy from a considerable distance.

Compared with these sharp and farsighted denizens of the forest and the mead, the mole, whose eyes are so very minute and well concealed by its fur that popular opinion supposes it to be entirely deficient in these important organs, seems to be but ill provided for; but its limited powers of vision perfectly agree with its subterranean life; and when during the summer months it sallies forth in quest of nocturnal prey (such as birds, mice, frogs, and snails), its eyes, which are furnished with a muscle that enables the animal to withdraw or to employ them as circumstances may prompt, render it all the services it requires. Though it has no external ears, as these would very soon be choked up with earth, yet it is amply provided with the means both of hearing and smelling—senses which, in its peculiar situation, are of far more importance than sight.

The Slepetz (*Spalax typhlus*), a small subterranean rodent



. typhlus.

of Eastern Europe, is even totally deprived of vision, as its rudimentary eyes, scarcely larger than a pin's head, are completely covered with the skin, and hence we may infer that this determined burrower hardly ever leaves his underground domains.

The most acute sense of the chamois is, beyond all doubt,

that of smelling. From a surprising distance these swift-footed ruminants of the Alpine world scent the huntsman standing in the wind, both at the same elevation as themselves and from the lower regions, as the warmer air-currents ascending from the deeper valleys bring along with them the emanations of man. Then, at this first symptom of danger, every sense is exerted to the utmost to find out the exact spot of impending peril. They restlessly hurry to and fro, or, anxiously on the watch, huddle together with far-outstretched necks. The ear and the eye strive to emulate the distended nostrils. When at length the chamois espy their enemy, they are more calm; while as long as they merely scent without seeing him, their agitation is excessive, from not knowing where to direct their flight. While the huntsman remains motionless, they likewise stand still, eyeing him all the time with the keenest attention; but as soon as he moves, they dart away with arrowy speed.

The scent of the dog is likewise of wonderful acuteness, and perhaps unrivalled among the quadrupeds. It directs, as it were, all his actions, and renders his services invaluable to the huntsman; for, with the assistance of this unerring guide, the dog smells the emanations of the game, which totally escape the grosser human sense, and follows exactly the path the object of his pursuit has taken. By means of his scent he knows how to find out his master among thousands, and to trace him for miles. It is, in one word, the most perfect of his senses; for, though he can hear well, his eyesight is not remarkably good. The internal structure of his nose gives his scent this extraordinary sharpness, as the convolutions of its cavity, which the air traverses in the act of inspiration, are exceedingly complicated, and it moreover branches out into sinuses or hollows of considerable extent, so that the olfactory nerves spread over a vast surface.

The kangaroo and the bison are indebted for many a timely warning to the great acuteness of their scent; and the thirsty camel, wellnigh sinking under the weight of his privations on his long march through the sandy desert, frequently detects by its means the distant stream or fountain. Then new vigour animates his weary limbs, with distended nostrils he sniffs the air, and, hastily rushing to the spot, quaffs in long draughts the refreshing waters.

In other quadrupeds the sense of feeling is particularly acute.

The thick skin of the elephant is indeed far from being distinguished in this respect, nor has he reason to regret its obtuseness while roaming through the thickets; but the termination of his long hollow trunk is endowed with an exquisite delicacy of touch, so that by means of this wonderful organ, which combines a giant's strength with the flexibility of a willow-wand, he is able not only to uproot trees and to raise prodigious weights, but to pick up the minutest objects from the ground. Its length supplies the place of a long neck, which would have been incompatible with the support of the large head and its weighty tusks; he makes use of it as efficiently as a hand in the performance of many important offices; it pumps up the enormous draughts of water, which, by its recurvature, are turned into and driven down the capacious throat, or spouted in refreshing showers over the body; it serves him to strike down the assaulting tiger with one tremendous blow, or to raise with delicate attention a child upon his back; and, to sum up its capabilities in one word, it combines every function and renders every assistance which the intelligent elephant required to raise himself above the level of the brutal rhinoceros or the stupid hippopotamus.

The long whiskers of the felidæ are delicate organs of the sense of feeling; but those of the shrews even surpass them in sensitiveness of touch, and seem to make amends to these active little creatures for the smallness of their eyes, which are almost hidden in the surrounding hairs, and formed but for twilight vision. Thus armed, they feel at a distance of eight or nine inches the slightest motion of the air, and the mere bending of a finger held out to them unseen suffices to alarm them. The utmost delicacy of touch, so as almost to reach the limits of credibility, is however possessed by the bats, who need no collision with any object to be advertised of its vicinity, but in the midst of darkness avoid any object that presents itself with the same unerring certainty as in the light.

Spallanzani, having observed this wonderful power, instituted a series of experiments, the results of which proved that bats when deprived of sight by the extirpation of the eyes, and as far as possible of hearing and smell by the obliteration of the external passages of those senses, were still capable of directing their flight with the same security and accuracy as before.

steering their course through passages only just large enough to admit them without coming into contact with the sides, and even avoiding numerous small threads which were stretched across the room in various directions—the wings never, even by accident, touching any of them. These marvellous results led him to believe that these animals are endowed with a sixth sense, the immediate operation as well as the locality of which is, of course, unknown to and inappreciable by us; but the sagacity of Cuvier removed the mystery without weakening the interest of these curious facts, by referring to the flying membrane as the seat of this extraordinary faculty. According to his view of the subject, the whole surface of the wings on both sides may be considered as an enormously-expanded organ of touch of the most exquisite sensibility; and it is, therefore, by the varied modification of the impulsion of the atmosphere upon this surface that the knowledge of the propinquity of foreign bodies is communicated.

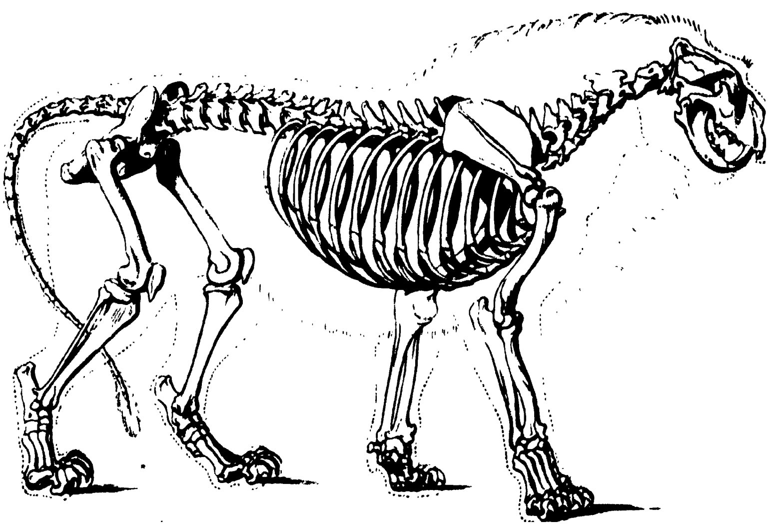
But touch is not the only sense which is highly developed in the bats, for the vast extent of the shell of the ear in the insectivorous species is undoubtedly of great assistance in the collection of sounds, and their smell is also wonderfully acute. In many of them, particularly in the rhinolophidæ—whose habits are more completely lucifugous and retired than any others, and who are found in the darkest penetralia of caverns, and other places where there is not even the imperfect light which the other genera of bats enjoy—the nose is furnished with foliaceous appendages, formed of the integument doubled, folded, and cut into the most curious and grotesque forms—an organisation evidently intended to give increased power and delicacy to the organ of smell, and thus to supersede the sense of vision in situations where the latter would be unavailable. Thus admirably equipped for nocturnal flight, the bats launch forth in quest of their insect prey,

Rhinolophus.

which, though screened by the veil of darkness, vainly endeavours to escape detection.

According to their various modes of life, the quadrupeds are amply provided with the means of defence or aggression. The carnivorous animals, destined to prey upon others, required, of course, to be specially equipped for active war; and as the seal of perfection is stamped upon all the Almighty's works, their structure exhibits, in the greatest imaginable degree, every quality which a life of rapine and violence requires.

Thus, for instance, the skeleton of the lion shows, in all its parts, a masterly combination of lightness of form with colossal power. The spine is flexible yet of great strength, while the



extent and robustness of the lumbar portion of the vertebral column seem at once adapted for that flexibility, and for the location of powerful muscles. The ribs are narrow and far asunder, the limbs so constructed as to afford the greatest facility and extent of motion, and the massive proportions of the cranium and jawbone give evidence of the enormous development of muscular power necessary for cutting and tearing in pieces the hard tendinous portions of the animal's prey.

The smaller felidæ, less formidable by their muscular strength, make up for this deficiency by a still greater activity in their movements, and a considerable expertness in climbing. The leopard creeps through the thickets with a serpent's flexibility, and when pursued by a more powerful foe frequently escapes upon the trees. There also the wild-cat seeks his prey, and the ferocious lynx, lying in ambush among the branches, springs down upon the back of the unsuspecting deer, and soon brings him to the ground.

In the weasel tribe the legs are shorter, the vertebral column elongated and in the highest degree flexible, the head small and slender; a structure by which they are enabled to creep through extremely narrow holes and crevices, in quest of the rats, mice, moles, and small birds on which they prey.

The bears, who live both on vegetable and animal food, require neither the retractile claws of the felidæ, nor their prodigious spring. The plantigrade form of their foot enables them to walk with firmness and solidity, to climb trees, or to dig the ground in quest of the food from which they derive their nutriment. In spite of their uncouth appearance and clumsy gait, they are capable of great activity; and the larger terrestrial species know how to defend themselves against the most formidable enemies, either felling them with a blow of their forepaws, or stifling them in a murderous embrace.

The elongated form of the Polar bear, and his short broad paws, enable this tyrant of the Arctic shores to swim with the greatest facility; and thus every member of the family is admirably fitted out for his peculiar field of action.

Destined to perform an important part in the economy of Nature, by cleansing the earth of the decaying carcases of the larger beasts, whose remains might otherwise infect the atmosphere with pestilential effluvia, the hyænas are not so well armed for active war as the felidæ, having neither their retractile talons nor their terrific bound. Their hind-legs are comparatively feeble; for, in harmonious accordance with their mode of life, the chief strength of their body is thrown into their forequarters, so as to enable them to disinter corpses from their graves, or to make themselves burrows in the earth, into which they retire during the daytime. For this purpose their claws are extremely strong, and the enormous power of their jaws and

solidity of their teeth are equally well adapted for crushing the hardest bones, so as to leave undevoured no part of the carrion on which they chiefly feed. Their nocturnal habits protect them from many a hostile collision, though when attacked they are far from being contemptible opponents.

The seals play among the fishes a part similar to that of the cat tribes among the herbivorous quadrupeds. For this purpose they are not only beautifully formed for swimming, both by the structure of their finlike limbs, their tapering body, and the strong muscles of their spine, which bend it with considerable force, and thus greatly assist propulsion; but they are also furnished with sharp and many-pointed teeth, excellently adapted for seizing, holding, and tearing the fishes, the activity of whose motions, no less than their scaly surface and even rounded form, render such a structure absolutely necessary. When on land or on masses of ice, where they love to bask in the sun, their slow and awkward movements expose them to many dangers; but they make up for this deficiency by their caution and watchfulness, seldom venturing from the shore, so as to be able at the approach of danger to plunge immediately to the bottom of the water, and seldom sleeping longer than a minute without moving their heads to ascertain whether anything suspicious is going on.

The cetaceans, particularly the whales, are in general of a pacific disposition, and will rather avoid a hostile encounter than boldly face it; but when attacked by other monsters of the deep, by the terrible swordfish or the formidable thresher, their tail becomes a terrific weapon of defence. The annals of the whale-fishery are full of instances where a single blow of this monster club has cut the pursuing boat down to the water's edge, or hurled the unfortunate harpooner high into the air. The sperm-whale sometimes also uses his enormous head as a kind of catapult or ram, to stave a boat, or, turning on his back, he endeavours to crush it between his jaws.

Though destitute of claws, the monkeys find ample means of safety in their arboreal life, their cunning vigilance, and their amazing agility in climbing. Bounding from bough to bough, they will pass through the most entangled forests with surprising swiftness, and mock the tiger-cat in his pursuit, or baffle the huntsman's aim. The apes upon the Rock of Gibraltar, although

The bison of the North American prairies is equally dangerous when excited, and the aurochs of Lithuania defies every carnivorous animal of his native forest. The long, twisted, and pointed horns of the eland (*Damalis orcas*) are sufficient to pierce a man through-and-through by one thrust, and even the horns of the goat can inflict severe wounds.

It may be observed as a general rule among the cervine and antelopine races, that in proportion to the smallness of their horns they seem endowed with an additional degree of speed. The roebuck and the chamois are proofs of this: the horns of both are but ill-calculated for vigorous defence, yet both are proverbial for their swiftness, and thus avoid many dangers with which they would be unable to cope. The graceful dark-eyed gazelle, the favourite of the poets of the East, whose weak horns can hardly afford the slightest resistance to attack, bounds across the desert with such amazing fleetness, that it seems to skim over the surface like a bird.

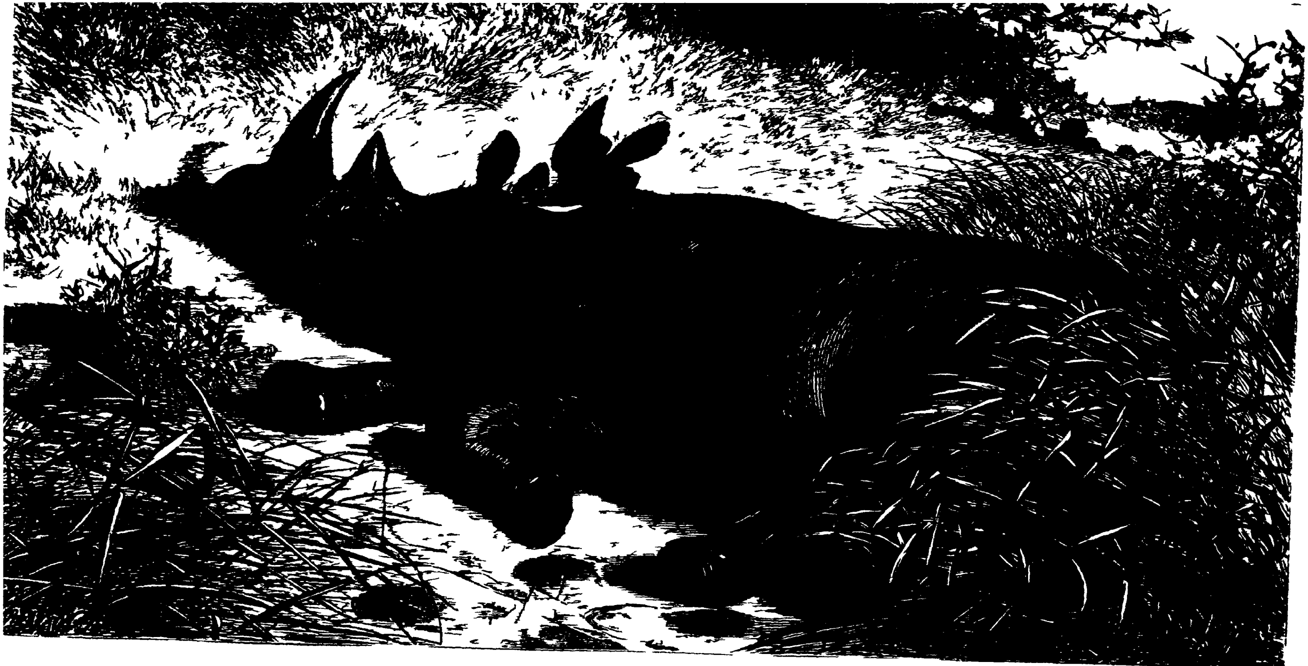
The horses, to whom a horned front has been denied, find compensation in their hard and solid hoofs, with which they deal out such blows as to make many an enemy repent having approached them too nearly. Moreover, in the wild state the various species of this noble animal live in wide-extended plains, avoiding forests and steep places; so that, with the aid of their acute senses and wonderful speed, they can both perceive danger at a considerable distance, and avoid it by a rapid flight.

The giraffe seems at the first glance a rather helpless animal, ill-provided with the means of escaping the crafty attacks of the lion or the panther, particularly as in the vast arid plains through which he roams his towering height makes him conspicuous from an immense distance. His colossal stature, however, is far less frequently a source of danger than of security; for his large, dark, and lustrous eyes are able, by their lateral projection, to take in a wider range of the horizon than is subject to the vision of any other quadruped; and their efficacy must naturally be much increased by their sweeping

over the plain from a height of seventeen feet or more. During the hours of darkness, the large, erect, and pointed ears of the giraffe no doubt render him as trusty services as the keenness of his vision by day. When flight becomes necessary, he bounds away in a graceful undulating canter; or, when driven to battle, strikes out so powerfully with his well-armed feet, as to defeat even the lion. His horns, small as they are, and muffled with skin and hair, are likewise no contemptible weapons, when, with a sidelong sweep of the neck, he levels them at full swing against his adversary's head.

Of all the quadrupeds the sloth was supposed to be the most helpless; but modern travellers, who have had occasion to observe him in his native haunts, have fully corrected this erroneous opinion. The colour of his hair so strongly resembles the hue of the moss which grows on the trees, that even the falcon-eyed Indian, accustomed from his earliest infancy to note the slightest signs of forest-life, is hardly able to distinguish him from the branches to which he clings. This no doubt serves him as a protection against many enemies, and when discovered he defends himself most vigorously with his formidable claws; and woe to the tiger-cat or tree-snake that comes within their reach!

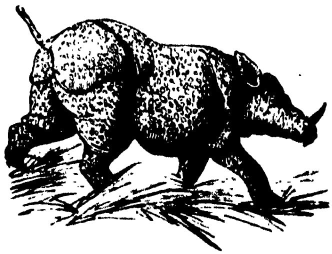
The great ant-eater, to whom Nature has denied sharp teeth and a rapid flight, who is unable to burrow or to roll himself up in a ball, still ranges through the wilderness in perfect safety, and fears no hostile encounter, for he has full reliance on his powerful forelegs and their tremendous claws. Dr. Richard Schomburgk had an opportunity of witnessing how a young ant-eater made use of these formidable weapons. On the enemy's approach it assumed the defensive, but in such a manner as to make even the boldest aggressor quail; for, resting on its left forefoot, it struck out desperately with its right paw. Assailed from behind, it wheeled round with the rapidity of lightning; and on being attacked from several quarters at once, threw itself on its back, and fought with both its forepaws, uttering at the same time an angry growl of defiance. In fact, the great ant-eater is so formidable an opponent, that he is said not unfrequently to vanquish even the jaguar; for the latter is often found weltering in his blood, with ripped-up bowels—a wound which the claws of the ant-eater alone are able to inflict.



RHINOCEROS AND ITS BIRD GUARDIAN. [SEE PAGE 371.]

The monstrous pachydermata or thick-skinned quadrupeds—the elephant, the rhinoceros, the hippopotamus—are gifted with other means of defence. Relying on his enormous weight, the elephant first strikes down his assailant with his trunk, and then crushes him into a shapeless mass by the pressure of his foot.

Though naturally of a quiet and inoffensive disposition, the rhinoceros when provoked or attacked charges with great impetuosity, and either tramples his adversary underfoot, or rips him up with his horn, which, though short and blunt, is a most effective weapon. To all these means of preservation may be added an extraordinary acuteness of smell and hearing, and that remarkably thick skin which furnishes a name to this order. In the rhinoceros particularly this characteristic is so highly developed that its hide is musketproof, and becomes as effectual for defence as if the animal were encased in a coat-of-mail.



The Rhinoceros.

The hippopotamus, on the other hand, although possessed of a very thick skin, is destitute either of proboscis, tusks, or horns. His habits are aquatic, and he retreats into deep water in the moment of danger, and bids defiance to all enemies of the land. To add to his security, his ears, nostrils, and eyes are all on the same plane, on the upper level of the head; so that the unwieldy monster, when immersed in his favourite element, is able to draw breath, and to use three senses at once for hours together, without exposing more than his snout.

The rodents, the smallest and the weakest of the quadrupeds, have indeed but feeble arms to oppose to the larger animals of which they are the prey; yet their caution, agility, and nocturnal habits preserve them from many perils. The hare is probably, for its size, the most defenceless quadruped yet discovered. It has neither tooth nor claw to repel an enemy; it can neither climb the trees nor burrow in the earth, nor dive into the water nor fly into the air, like the squirrel or the mole, the beaver or the bat; yet how admirably has Nature provided for its safety! Its

whole organisation seems to indicate the extreme of watchfulness in perceiving danger, and of speed and cunning in avoiding it. Similar qualities characterise the squirrels, who may be called the hares of the trees, from their great agility in climbing, and their prodigious leaps from bough to bough. As is well known, the squirrel is an admirable nest-builder. His summer cage, in which the young are born, is placed nearly at the extremity of a slender bough, and is comparatively frail; while his winter residence is almost invariably situated in the fork of some tree, generally where two branches start from the trunk, and is so well concealed by the boughs on which it rests, that it requires a practised eye to detect it. Thus the squirrel never forsakes the trees, which afford him both food and shelter.

Most rodents, however, seek a refuge from their enemies in subterranean burrows, frequently driving a whole labyrinth of tunnels through the soil. The rabbit is a familiar example; but however active he may be in excavating sandy heaths and downs, his labours are inferior both in extent and ingenuity to those of the prairie-dog (*Arctomys ludovicianus*), a species of marmot which inhabits the vast grass-plains of North America, and owes its popular name to the short yelping sound it is fond of uttering. These pretty little rodents frequently assemble in such numbers that thousands of their burrows are dug in close proximity to each other, and honeycomb the ground to such an extent as to render it quite unsafe for horses. The scene presented by one of these 'dog-towns' or villages is extremely curious, and well repays the trouble of a visit.

'The prairie-dogs,' says the Hon. C. A. Murray, 'burrow under the light soil, and throw it up round the entrance to their dwelling like the English rabbit; on this little mound they generally sit, chirping and chattering to one another like two neighbour-gossips in a village. I do not know what their occupations are, but I have seen them constantly running from one hole to another, although they do not ever pay any distant visits. They seem on the approach of danger always to retire to their own home; but their great delight apparently consists in braving it, with the usual insolence of cowardice, when secure from punishment; for, as you approach, they wag their little tails, elevate their heads, and chatter at you like a monkey, louder and louder the nearer you come; but no sooner is the hand raised to any missile, whether gun, arrow, stick, or stone,

than they pop into the hole with a rapidity only equalled by that sudden disappearance of Punch, with which, when a child, I have been so much delighted in the streets and squares of London.'

Many rodents burrow not only for safety, but for the purpose of establishing subterranean provision-stores. Among these provident little animals none is more famous than the hamster, whose enormous cheek-pouches have already brought him under our notice. His dwellings are formed under the earth, and consist of more or fewer apartments, according to the age of the animal. A young hamster makes them hardly a foot deep, an old one sinks them to the depth of four or five feet; and the whole diameter of the residence, taking in all its habitations, is sometimes eight or ten feet. The principal chamber is lined with dried grass, and serves for a lodging; the others are vaults destined for the preservation of provisions. Each hole of the male hamster has two apertures—the one descending obliquely, which serves him to escape in case of a forcible irruption into his premises; and the other perpendicularly, through which he makes his usual ingress and egress. The holes of the females, who never reside with the males, have more numerous passages, and frequently six or eight perpendicular openings.

In the beaver the burrowing faculty expands into a wonderful building instinct, such as no other quadruped possesses. In summer, this interesting rodent leads a solitary life, in burrows which he digs along the banks of the lakes and rivers of Northern America; but as soon as the first night-frosts signalize the approach of chilly autumn, he leaves his summer seat, and forms a society with other individuals of his kind, for the purpose of erecting his winter lodge. The associates select, if possible, a spot where the water is always so deep as not to freeze to the bottom in winter; but in small rivers and creeks, in which the water is liable to be drained off when the back-supplies are congested by the frost, they, with wonderful sagacity, provide against that evil by raising a dam across the stream, almost straight where the current is weak, but where it is more rapid curving more or less with the convex side opposed to the current, so as to break its violence. The materials made use of are drift-wood, green willows, birch, and poplars, intermixed with mud and stones. As if it had been planned by a skilful engineer, this dam opposes a sufficient barrier to the force both of

water and ice; and as the trees employed in constructing it generally take root and shoot up, it forms in time a green hedge in which the birds build their nests.

By means of these erections the water is kept at a sufficient height, for it is absolutely necessary that there should be at least three feet of water above the entrance of the lodge, without which, in the hard frosts, it would be entirely closed; for the entrance is not on the land-side, but always under water, so as to secure the inmates from the attacks of wild animals.

The lodges, each of which is made large enough to contain about four old and six or eight young ones, are erected either along the dyke or on the banks of the river or lake, and plastered over with mud, which soon freezes as hard as stone, and prevents the wolverine from disturbing them during the winter. They are built of the same materials as the dam, of an oval or beehive shape, and of a diameter of six or seven feet. The interior forms only a single chamber, resembling an oven; and at a little distance is the magazine for provisions, where they keep in store the roots of the yellow waterlily and the branches of the black spruce, the aspen, and the birch, which they are careful to plant in the mud. Their magazines sometimes contain a cartload of these articles, and the beavers are so industrious that they are always adding to their store. They convey the mud and stones with their small forepaws, holding their load close up between them under their throat, while they always drag the wood with their teeth.

When the beavers settle on the banks of a stream, they cut their wood above the spot which they have selected for their lodges, and use the current to convey it where it is wanted. The precautions they take in felling trees are truly wonderful. When the trunk has been cut all round and is near its fall, they measure every bite, so that it must necessarily fall into the water and not towards the land, which would render all their labour useless. Thus, throughout all the building operations of the beaver, we find an attention paid to physical laws which is not always displayed in the works of human architecture.

The ondatra, musquash, or muskrat, a rodent common throughout Canada and the Hudson's Bay territories, and well known in England by its valuable fur, so greatly resembles the beaver in its way of life, that the Indians, who are keen ob-

servers of nature, call them brothers, but allow the latter the rank of primogeniture from his superior building abilities.

Essentially a bank-haunting animal, the musquash is never to be seen at any great distance from the water, where it swims and dives with consummate ease, aided greatly by the webs which connect the hinder toes. It drives a large series of tunnels into the bank, branching out in various directions, and having several entrances, all of which open under the surface of the water. The tunnels are of considerable length, and they all slope slightly upwards, uniting in a single chamber in which the inhabitants repose. If the animal happens to live upon a marshy and uniformly wet soil, it becomes a builder, and shows great judgment in the selection of the site, invariably choosing some higher ground above the reach of inundation, or else raising its hut on an artificial foundation; for, though obliged to reside near flat submerged banks, where the soft soil is full of nourishing roots, it requires a dry home to rest in.

The huts are about two-and-a-half or three feet in diameter, plastered with great neatness in the inside, and covered externally with a kind of basket-work of rushes, carefully interlaced together so as to form a compact and secure guard impermeable by water. They are sometimes built in such numbers together, that they may be compared with villages. In winter they are generally covered with a thick mantle of snow, under whose shelter the industrious musquash is able to procure water, or to reach the provisions stored up in its subterranean home. Thus it lives in abundance and security, for the marten and the minx are too averse to the water, and the otter too bulky, to be able to penetrate into its tunnels. But when the snow melts, and the diminutive huts of the musquash appear above the ground, the Indian steals up, and, dashing them to pieces with his spear and tomahawk, secures the unfortunate inmates. Great numbers are also destroyed by the spring inundations, and in severe winters they are almost extirpated from some localities by the freezing of the swamps which they inhabit.

Besides the generality of the rodents, we find many other burrowers among the more helpless or timid quadrupeds—such as the armadillos, the manis, the smaller ant-eaters—or even among the carnivora, such as the fox or the badger; but as it would lead me too far were I to follow the whole number in their

subterranean labours, I shall confine myself to a short description of the underground residences of our native mole and of the Australian duckbill. The former not only digs tunnels in the ground, but forms a complicated residence, which may rival the more celebrated erections of the beaver.

'The district or domain,' says Mr. Bell, in his 'History of British Quadrupeds,' 'to which an individual mole confines himself, may be termed his encampment. Within its limits, or at least in immediate communication with the district, all the labours of the animal are pursued. It consists of the habitation or fortress, from which extends the high-road by which the animal reaches the opposite end of the encampment, and of various galleries or excavations opening into this road, which it is continually extending in search of food. The fortress is formed under a large hillock, which is always raised in a situation of safety and protection—either under a bank, against the foundation of a wall, at the root of a tree, or in some similar locality. The earth of which the dome covering this curious habitation is composed, is rendered exceedingly strong and solid by being pressed and beaten by the mole in forming it. It contains a circular gallery within the base, which communicates with a smaller one above by five nearly equidistant passages; and the domicile or chamber is placed within the lower and beneath the upper circular gallery, to which last it has access by three similar passages. From the chamber extends another road, the direction of which is at first downwards for several inches; it then rises again to open into the high-road of the encampment. From the external circular gallery open about nine other passages, the orifices of which are never formed opposite to those which connect the outer with the inner and upper galleries; these extend to a greater or less distance, and return, each taking an irregular semicircular route, and opening into the high-road at various distances from the fortress.'

Being a peculiarly aquatic animal, the duckbill always makes its home in the bank of some stream, almost invariably at a wide and still part of the river. There are always two entrances to the burrow, one below the surface of the water, and the other above, so that the animal may be able to regain its home either by diving or by slipping into the entrance which is above the surface. This latter entrance is so well hidden by

overshadowing grasses and drooping herbs that even the keenest inspection frequently fails to detect it. The burrow itself extends in numerous curves and windings to a length of thirty or forty feet, and at its upper extremity is placed the nest, an excavation of a somewhat oval form, much broader than the width of the burrow, and well supplied with dry weeds and grasses, upon which the young may rest.

Burrow of the Duckbill.

Most of the mammalia whom Nature has clothed with spines or strong bony scales, increase the efficiency of their armour by the faculty of rolling themselves up into a ball, and thus opposing on all sides to the enemy a forest of spears or an impenetrable coat-of-mail. Contracting the strong muscular fibres with which its skin is interwoven, the hedgehog, when molested, presents nothing but its prickles to the foe, and the more the animal is irritated and alarmed the more firmly does it contract itself, and the more stiff and strong does its bristly panoply become. Thus rolled up, it patiently waits

till the danger is past; and however desirous the cat, the weasel, the ferret, and the martin may be to taste its tender flesh, they soon find out the uselessness of tooth or claw to force the stronghold; and though a well-trained terrier or a fox may now and then be found to overcome the resistance of a hedgehog, it generally remains secure—scarcely anything but a cold-water bath obliging it to unfold itself.

Rolling itself in like manner into a perfect sphere, the armadillo completely conceals its head and tail under its tesselated armour, so that no dog can force it to unfold itself; and the African long-tailed manis, hiding every vulnerable part under a rampart of trenchant scales, repels the assaults even of the panther.

Though unable to roll itself up so completely as the hedgehog, the 'fretful' porcupine makes up for this want by the greater power and length of its sharp quills, which, when attacked, it raises on every side like so many *chevaux-de-frise;* so that a beast of prey is hardly ever able to force the bristling phalanx, and man is almost the only enemy it has to fear. When driven to extremities, it is not satisfied with a passive resistance, but rushes upon its adversary, and always sideways, thus bringing into action the longest and sharpest of its quills. Notwithstanding its vigorous defence, it is frequently hunted in the sandy districts of Barbary. Well-beaten paths, and here and there a quill it may have lost, direct attention to its burrow among the prickly shrubs. The huntsmen widen the entrance with their swords, until a hoarse prolonged growl and the peculiar noise which the enraged porcupine makes on raising its quills warn them to be on their guard. Suddenly the creature rushes forth, but the well-aimed blow of a poniard stretches it into the dust. A fire is then kindled, and the animal buried under the embers; the quills are then easily separated from the roasted and excellently-flavoured meat.

In several quadrupeds the emission of scents or fluids of an offensive character constitutes an important means of defence. Thus, most of the members of the weasel tribe—as, for instance, the ferret or the polecat—emit, when irritated, a very disagreeable odour, which no doubt cools the warlike impetus of many an enemy; but the most highly-gifted animals in this respect are the skunks, which do full justice to their Latin generic

name—*Mephitis*. Their various species inhabit the cold and temperate regions of North and South America; and, implicitly relying on the strength of their talisman, they fly from no enemy, not even from man. Such is the intolerable odour of the secretion from their glandular pouches, which they have the power of ejecting on their pursuers, that the least quantity suffices to produce nausea and a sense of suffocation.

Prompted by the powerful instinct of self-preservation, many of the quadrupeds, singly too weak to oppose an effectual resistance to the attacks of their enemies, find an additional strength in the power of union. Thus, when assaulted by the jaguar, the wild oxen of the American llanos or grass-plains of the Orinoco form a ring, in the centre of which they place their calves, while the stronger animals turn their horns towards the enemy.

The wild horses of America likewise march in columns—these troops being headed by a vigorous male chief, who is constantly at their head, on travel or in battle, and is invariably followed under all circumstances. When the herd is disturbed by any object, they approach it within a certain distance, having the strongest individuals at their head, examine it attentively, and describe one or more circles round it. If it does not appear dangerous, they approach with precaution; but if the chiefs recognise any danger, and give an example of flight, they are instantly followed by the whole troop.

The peccari, a small hoglike pachyderm of South America, roams in herds of several hundreds through the tropical forest. When attacked, the whole band rushes furiously upon the enemy, so that even the puma and the jaguar do not venture to assault the main body, but merely hang on the outskirts ready to catch some unfortunate straggler.

For greater security the gregarious quadrupeds frequently set out a watch, upon whose steady attention they implicitly rely. When a troop of chamois is grazing in some Alpine solitude, one of the band, stationed at a short distance, is seen to cast an inquisitive glance around, or to raise its head, carefully sniffing the air, while the others are grazing or tilting at each other with their horns like frolicsome goats or deer. But as soon as the sentinel, espying danger, utters his shrill note of warning, they

suddenly stop, and rapidly follow him as he bounds away from the scene of peril.

In the Peruvian or Bolivian highlands, the she-vicuñas roam about in small herds, under the protection and guidance of a single male, who always remains a few paces apart from his harem, and keeps watch with the most sedulous attention. At the least sign of danger, he immediately gives the alarm by a shrill cry, and rapidly steps forward. The herd, immediately assembling, turns inquisitively towards the side whence danger is apprehended, advances a few paces, and then, suddenly wheeling, flies, at first slowly, and constantly looking back, but soon with unrivalled swiftness. The male covers the retreat, frequently standing still and watching the enemy.

Many of the monkeys likewise set out guards while plundering the fields. Thus, a troop of baboons will sometimes form a long chain, extending from the vicinity of their ordinary habitation to the garden which they happen to be engaged in robbing, and pitch the produce of their theft from hand to hand till it reaches its destination in the mountains. Should any disturbance occur, the guard utters a loud cry, and the whole band is out of sight in an instant.

In the Alpine solitudes, just below the region of perpetual snow, the social marmot enjoys its short summer under the protection of a watchful sentinel, who, at the approach of any danger, gives a shrill whistle, when they all retire into their burrows. Trusting to the attention of their guard, they are seen sporting in fine weather about the neighbourhood of their retreats, where they delight in basking in the sunshine, and frequently assume an upright posture, sitting on their hind-feet.

In a very different scene, on the waveworn rocks and desolate shores of the Polar seas, we find among the walruses and the seals the same protective instinct. In fine weather the former love to assemble on the ice, where they may be seen in herds, consisting occasionally of upwards of a hundred animals each. In these situations they appear greatly to enjoy themselves, rolling and sporting about, and frequently making the air resound with their bellowing, which bears some resemblance to that of a bull; but these wary animals take the precaution of having a sentinel to warn them of any danger to which they may be liable. So universal seems the observance of

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this precaution amongst their species that Admiral Beechey, who had many opportunities of observing them in Spitzbergen, scarcely ever saw a herd, however small, in which he did not notice one of the party on the watch, stretching his long neck in the air every half-minute, to the utmost extent of his muscles, to survey the ground about him. In the event of any alarming appearance, the sentinel begins by seeking his own safety; and as these animals always lie huddled upon one another, the motion of one is immediately communicated to the whole group, who, scrambling to the edge of the ice as fast as their awkwardness permits, tumble into the water, head first if possible, but otherwise in any position in which chance may have placed them.

Some quadrupeds find a remarkable protection in the company of animals belonging not only to the same genus but to a totally different class. Thus the rhinoceros is frequently accompanied by a bird (*Buphaga africana*), which feasts upon the larvæ that settle in his skin. As the range of his small and deep-set eyes is impeded by his horn, he can only see what is immediately before him, so that, if one be to-leeward of him, it is not difficult to approach within a few paces. But the bird sees all the better, and flying away at the first approach of danger, awakens the short-sighted brute's attention by a shrill cry of warning. In this manner the insects which plague the rhinoceros become the indirect means of his preservation from many perils, as, but for them, his winged monitor would have no inducement to seek his company.

The African buffalo possesses a similar guardian in the *Textor erythrorynchus*. When the beast is quietly feeding, the bird may frequently be seen hopping on the ground, picking up food, or sitting on its back, and ridding it of the insects with which its skin is infested. The sight of the bird being much more acute than that of the buffalo, it is soon alarmed by the approach of any danger; and when it flies up, the buffalos ins their heads to discover the cause which has led to flight of their companion.

The smaller monkeys of the tropical forests of fond of associating with their more powerful congeners, in friendly assistance they find a compensation for their ness. Thus the saïmiri clings to the back of the

who, at the beginning of their acquaintance, endeavours to shake off his burden; but, finding it impossible, soon learns to love his companion, so that, when the saïmiri is busy chasing insects, his friend, before leaving the spot, first gives him notice by a gentle cry.

A still more remarkably disinterested friendship is sometimes found to unite quadrupeds belonging to different families. There are many examples of lions having spared the life of dogs that had been thrown into their dens for food, and of the strongest affection having been formed between them. One of these couples existed a few years ago in the Zoological Gardens at Antwerp, and it was most interesting to see the mighty African throwing himself on his back, and playfully tossing his tiny friend between his enormous paws. The dog—a regular spoilt child—frequently plagued his mighty comrade, though without ever making him impatient or angry.

Even the breast of the tiger has been known to expand to the genial influence of friendship, and to entertain feelings supposed to be totally alien to its nature. Captain White, the commander of an English merchantman, having been presented with a tigress, during a voyage to Cambodia, used to feed her every day with a live dog. After playing some time with its victim, as the cat with a mouse, the tigress, seizing it by the neck, divided the arteries, and walked up and down, lashing with its tail, and holding it in its mouth while sucking the blood. One day a young dog was thrown into the cage, who, possessed of a more than common courage, and resolved not to submit quietly to his fate, jumped up to the tigress, and bit her in the nose. An instant death might have been expected to be the punishment of this audacity; but the impotent fury of the little dog seemed to please the formidable brute, who, gently warding off the attack, endeavoured by her caresses to gain the confidence of her pigmy adversary. In a short time friendship was established, and the two became inseparable.

The instinctive attachment of the domestic animals to man is of the highest importance to his welfare, as otherwise they would hardly have so patiently submitted to his yoke, or so willingly obeyed his commands. How could he have tamed them? How could he have trusted them, if they had not been impelled by their nature to seek his company—to become, not his unwil-

ling slaves, but his grateful and affectionate servants? Hence there can be no doubt that this feeling has been implanted in them with a view to his benefit, for their services are all the more valuable for being cheerfully rendered. The dog is preeminent for this inborn attachment to man. In South America there are numerous wild dogs that have enjoyed the liberty of the savannah for several centuries; they descend from European dogs, and have multiplied in the wilderness, where they roam about like beasts of prey. In the East, particularly in Egypt, there are also many masterless dogs, almost equally savage; but in both places these wild dogs, when caught, and treated with kindness, soon become tame, and as attached to their masters as those dogs which have been the trusty companions of man through a long series of generations. A similar affection is testified by the horse; and even the poor ass is not only a pattern of submissive meekness, but is susceptible of great attachment towards his master, whom it will scent at a considerable distance, distinguish in the midst of a crowd, and faithfully follow.

But besides the animals which are particularly formed to be the companions of man, even the wild denizens of the forest, whom he has deprived of their liberty, soon grow attached to his rule when treated with humanity and kindness. Many instances of the attachment of lions and other carnivorous animals to their keepers might be cited, and it is very much to be doubted whether any mammalian exists of so ferocious or so stubborn a nature as to be totally untameable.

Quadrupeds, being thus open to friendship, may also naturally be expected to display the sentiments of parental, filial, and connubial affection. Monkeys are peculiarly fond of their young; they tend and watch them in the most singular manner, and appear to pursue a plan both as to their nurture and education, often severely correcting them if stubborn or disinclined to profit by their example.

The ice-bear, the dread and terror of all other animals that come within its reach, is remarkable for the strength of its parental affection; and this same passion inspires the most timid ruminants in the hour of danger with an almost preternatural courage. Then the hind forgets her usual caution in the resolute defence of her offspring, and boldy confronts the

hunter for the purpose of diverting his attention from her young; then the she-buffalo will rush at the tiger, and baffle the monster by the fury of her onset.

The marine tribes are no less distinguished for parental affection than the land quadrupeds. The females of the Arctic walrus, if attacked on the ice, always first secure the safety of their young by casting them into the sea, and then, returning to their enemy, give vent to their rage. The Greenland whale is extremely attached to her young, and often rushes into the most imminent danger, and even upon certain death, to rescue or defend it. The whalers take advantage of this affectionate attachment, and strike with the harpoon the young whale, quite sure that the mother will before long approach for the purpose of saving her offspring, but too frequently, in fact, to perish with it.

The affection of the female opossum and of the other marsupial quadrupeds is aided by the pouch which Nature has so curiously contrived within herself. Here the young—which, when first born, are in a very undeveloped state, being minute, blind, naked, and shapeless—remain constantly adhering to the teats, which their mouth is just large enough to embrace, for fifty days, until they have attained the size of a mouse, at which period their eyes are opened, and their bodies are covered with hair. They may now be seen venturing occasionally from their hiding-place, which, however, still continues to afford them nourishment and shelter; there they find a warm bed during the cold nights; there, when they are hungry and thirsty, they seek the sources of refreshment; there they fly, as into a harbour of refuge, at the least apprehension of danger.

Our admiration increases when we come to examine more closely the beautiful harmony between the structure of the mother and that of her new-born offspring—a harmony designed with especial reference to each other's peculiar condition, and thus affording the most conclusive evidence of Creative foresight.

Although the new-born opossum or kangaroo is enabled by the muscular power of its lips to grasp and adhere firmly to the nipple, it seems to be unable to draw sustenance therefrom by its own unaided efforts. The mother is therefore provided with the peculiar adaptation of a muscle to the mammary gland, for

the evident purpose of injecting the milk from the nipple into the mouth of the adherent fœtus. But, as it can scarcely be supposed that the efforts of suction should always coincide with the maternal act of injection, and thus suffocation might easily ensue unless the aperture of the windpipe were guarded by some special contrivance, we find the latter projecting, as in the cetaceans, into the nasal cavity, where it is closely embraced by the muscles of the soft palate. The air-passage being thus completely separated from the fauces, the injected milk passes in a divided stream on either side the windpipe to the gullet; and the little creature breathes and sucks at the same time, without one of these vital functions ever interfering with the other!

A circumstance well worthy of remark is, that in the animals parental affection and filial attachment last no longer than the necessity of maternal care. As soon as the young are able to provide for themselves, as soon as they can play their part in the world without any further assistance, repulsive coldness, or even enmity, takes the place of former tenderness, and creatures until then inseparable depart from each other as perfect strangers. This limited extent of animal feeling is in perfect harmony with the limited sphere of animal existence.

The services which the quadrupeds render to man are of such paramount importance that without their assistance he never could have become a civilised being. As the existence of the animals in general depends upon that of the vegetable kingdom, and as among the animals each higher grade of organisation rests upon the foundation of an inferior type, so without the possession of his domestic cattle, man could never have risen to the superior rank he occupies among the denizens of the earth. In fact, they are almost as essential to the perfection of his being as his reason itself, as without them he never could have developed his rational faculties; and thus there can be no doubt that they have been specially formed for his service. What would agriculture be without the horse or the ox? and what would England be without agriculture?—the dwelling-place of a few skin-clad barbarians!

In many countries the very existence of man depends upon the possession of a single mammalian. The Bedouin cannot be thought of without the dromedary, or the Samoyede without the

reindeer; the life of the Eskimo is bound to that of the seal or the walrus, and the Indian hunter would disappear from the face of the earth if the deer were no longer to range the forest, or the bison to scour the boundless prairie. The chase of the whale, of the seals, and of several other animals, not only plays an important part in the annals of commerce but forms a conspicuous feature in the history of the human race, as it has influenced the destiny of numerous nations, and contributed more than anything else to bring the remotest parts of the earth within the influence of European civilisation. The sable was the magnet which led the Russians from Siberia to Kamtschatka, and the still more valuable sea-otter conducted them to the Aleütic chain, and to the opposite coast of America, as the seal attracted them to the desolate solitudes of the Sea of Behring. The English and American whalers have followed the huge cetaceans both into the icy channels of Baffin's Bay and the Antarctic Ocean; and it is highly probable that, but for the sperm-whale, the South Sea islanders would have remained until now in total seclusion from the rest of mankind. Thus Providence has made use of a few animals as the instruments for extending the intellectual horizon of man, and for rendering the most inhospitable countries tributary to his wants!

As the mammalia are his nearest relations, in a physical point of view, they are also endowed with an intelligence superior to that of the other animals, and not seldom prompting them to actions which seem rather to belong to the sphere of reason than to that of brutal instinct. The chimpanzee, for instance, will lock and unlock a door or drawer, will thread any needle, and cannot be taken in by the same thing twice.

A dog in a monastery, perceiving that the monks received their meals by rapping at a buttery-door, contrived to do so likewise, and, when the allowance was pushed through, and the door shut, ran off with it. This was repeated till the theft was detected.

Another dog, belonging to Mr. Taylor, a clergyman who lived at Colton, near Wolseley Bridge, was accused of killing many sheep. Complaints were made to his master, who asserted that the thing was impossible, because he was muzzled every night. The neighbours persisting in the charge, the dog one night was watched, and he was seen to draw his neck out of the muzzle,

then to go into a field and eat as much of a sheep as satisfied his appetite. He next went into the river to wash his mouth, and returned afterwards to his kennel, put his head into the muzzle again, and lay very quietly down to sleep.

Mr. Morand, a surgeon in Paris, had taken into his house the dog of a friend which had broken its leg, and good-naturedly cured it. Some time after, this dog scratched at the door of Mr. Morand's study, and, on being admitted, introduced another dog, to whom the same accident had happened, and who could hardly crawl along after his guide. The first dog plainly showed by his caresses what he wanted, and the surgeon, admiring his sagacity, took charge of his protégé and cured him likewise.

Whole volumes might be filled with similar well-authenticated instances of the dog's intelligence; and it is surely not one of the least interesting Harmonies of Nature that the animal which, by its courage, fidelity, attachment, and obedience, is most fitted to be the companion of man should also have been gifted with a sagacity necessary to give their full value to all its other qualities. The ox is able to perform his patient duties without any great display of intelligence; docility and obedience, in addition to considerable muscular strength, were all the qualities he required to play his part among our household animals; while the nobler horse, destined for more brilliant though not more useful services, has been endowed with a sagacity very superior to that which has been allotted to the bovine races. His courage, strength, and fleetness, his symmetrical form and grandeur of deportment, are unalloyed by any quality injurious to other creatures, or calculated to create the aversion of man, whose orders he implicitly obeys, whose severest tasks he undertakes with a cheerful alacrity, and to whose pleasures he contributes with animation and delight. He understands the words and the signs of his rider; he knows exactly the road he has once travelled, and is able to find his way home through the darkness of the night. Like the dog, he is sensible of praise or reproof, and is filled with a generous emulation to vanquish his competitors in the race. Nor is this all, for, when called to bear our warriors to the battlefield, nothing can exceed his martial ardour. 'His neck is clothed with thunder; the glory of his nostrils is terrible; he paweth the valley, and rejoiceth in his strength; he goeth on to meet the armed men; he

mocketh at danger, and is not affrighted, neither turneth he back from the sword.'

As the elephant surpasses all that breathes on dry land in bulk and muscular power, his mental faculties also assign to him one of the first places in the animal creation. When tamed he becomes the most gentle and obedient of all domestic quadrupeds, and in most cases is exceedingly fond of his keeper, and soon learns to distinguish the various tones of the human voice, as expressive of anger, approbation, or command. His strength is rendered doubly serviceable to man by the intelligence he evinces in its use. He will load a boat with amazing dexterity, carefully keeping all the articles dry, and disposing them where they ought to be placed. In propelling wheel-carriages heavily laden up a declivity, he pushes them forward with his forehead and supports them with his knees.

In Ceylon, where the elephants are frequently employed in dragging and piling felled timber, they manifest an intelligence and dexterity which is surprising to a stranger, because the sameness of the operation enables them to go on for hours disposing of log after log, almost without a hint or direction from their overseers. Sir E. Tennent mentions two elephants thus employed in the yards attached to the Commissariat Stores at Colombo, who accomplished their work with equal precision and with greater rapidity than if it had been accomplished by dock-labourers. When the pile attained a certain height, and they were no longer able by their conjoint efforts to raise one of the heavy logs of ebony to the summit, they had been taught to lean two pieces against the heap, up the inclined plane of which they gently rolled the remaining logs and placed them trimly on the top.

The docility of the elephant is all the more surprising, as he is always originally the freeborn son of the forest (for he never propagates in a state of captivity), and is often advanced in years before being obliged to change the independence of the woods for the yoke of thraldom; while the dog has been the companion of man through many ages, and the acquired habits of successive generations have gradually moulded his physical and moral type to domesticity. What services might not be expected from an animal so sagacious as the elephant, were we able to train the species as we do the individual!

The mammalia are protected in various ways against the severe winter of the higher latitudes. Although they cannot, like the birds, exchange in a few days the chilly north for the mildness of a southern sky, yet many of them wander at the approach of the dreary season of cold and famine to a more hospitable clime. Then the musk-ox leaves the naked barren grounds of Arctic America for the less inclement forests; and the wild reindeer quits the flat coasts of the Polar Sea, where the mosses of the tundra provided him with his summer food, to seek in the thick pinewoods of Siberia a better shelter against the terrible blasts of the snowstorm.

Other quadrupeds fly from the winter into caverns or burrows, where they partly live upon the provisions which an admirable instinct taught them to collect during the summer, and partly fall into a profound sleep, from which they only awaken at the return of spring.

What would become of the slow marmot during the winter, when Alpine vegetation lies buried under a thick bed of snow, if bounteous Providence had not protected it by a deep lethargy both against the pangs of hunger (for its scanty pasture-grounds can only provide for the summer) and the attacks of the numerous enemies to whom it would infallibly have fallen a prey if obliged to migrate from its mountain solitudes? In early autumn it begins to excavate its winter dwelling, into which it retires with its whole family after the first snow-fall; and, after having closed the opening from within with stones, earth, and moss, lies down for its long rest of many months.

By a most admirable ordination of Providence its life is now reduced to the lowest ebb, that it may be preserved from total extinction. Its respiration becomes so slow that, during its six months of sleep, it draws its breath less frequently than during two days of its active existence, so that the fat which, during the abundance of summer, had collected upon its bones, suffices to keep up the glimmering spark of life. The palpitation of the heart is scarcely perceptible; the temperature of the body sinks to a few degrees above the freezing-point; the limbs are stiff, and almost totally insensible to injury.

Thus in their deep burrows, imbedded in soft hay, the marmots remain from October to the end of April, when they

are awakened from their torpidity by the warm sun of spring. But who tells them in their nightly caverns that the snow has disappeared from the turf where they spent a summer of enjoyment? How do they know that it is now time to exchange darkness for light, and that the aromatic Alpine herbs—their delightsome food—are once more clothing the mountain-ledge with verdure? Their awakening at the right time from their lethargy is as wonderful as their faculty of falling into that deep sleep which carries them so softly over the dreary winter, and changes distress and want into repose and ease. Though buried for months under the snow, winter is to them an unknown season, and, like the animals of warmer climates, their whole active life is spent in pleasure and abundance. Thus Providence has consulted not only their safety but their happiness; and indeed, on examining the whole series of the quadrupeds, we shall find that the chequered scene of their existence inclines to the sunny side.

The sloth, clinging to his branch, will express his satisfaction for hours together by a kind of purring; and even the bats—the emblems of melancholy—may frequently be seen chasing each other in some secluded spot, and merrily piping during their playful evolutions.

The sprightliness of the dolphin is proverbial, and has frequently been celebrated by both ancient and modern poets. His lively troops often accompany, for days together, the track of a ship, and agreeably interrupt the monotony of a long sea-voyage. As if in mockery of the most rapid sailer, they shoot past so as to vanish from the eye, and then return again with the same lightninglike velocity. Their spirits are so brisk that they frequently leap into the air, as if longing to enjoy themselves in a lighter fluid.

The leviathan cetaceans likewise love to indulge in sportive humours. A crowd of gregarious sperm-whales may be seen gambolling about on the vast wastes of the Pacific as lightly as the dolphin in the more confined waters of the Mediterranean. They will often swim in long lines, rhythmically sinking and rising as they rapidly proceed in their undulating course, or bask and sleep upon the surface, spouting leisurely, and exhibiting every indication of being at home. Sometimes a peculiarly high-spirited individual will jump out

of the water and remain suspended for a moment in the air, as if desirous of exhibiting his colossal size to the astonished sea-birds. On falling back again into his congenial element, high foam-crested fountains spout forth on all sides, and great waves spread in widening circles over the sea. Or else he raises his bulky head vertically on high, so that the deceived mariner fancies he sees some black rock looming out of the distant waters. But suddenly the fancied cliff begins to move, and brandishes playfully its enormous flukes in the air, or lashes the waters with such prodigious power that the sound rolls far away like thunder over the deserts of the ocean.

On the icy shores of Spitzbergen, the walrus bellows with delight while basking in the sun, and the sea-caves of Orcadia frequently resound with the joyful bark of the seal. On ascending from the banks of the ocean to the Alpine snows, we meet with similar expressions of happiness among the brute creation. There the timid marmot is seen playing with his comrades; and there, amidst precipices almost inaccessible to man, the chamois sportively push each other with their horns, or gambol about, revelling in their mountain liberty.

In one word, wherever we roam over the surface of the globe, we find that in their wild state the quadrupeds are in the enjoyment of a large share of happiness. They have indeed frequently to suffer from illness, privation, or the persecutions of their enemies, for no created being is exempt from pain; but much more frequently they enjoy the present without being troubled, like man, either by cares for the future, or the remembrance of the past. It is only in the domesticated state that the life of many a poor horse or dog is an uninterrupted chain of misery, to the shame of his barbarous master. When will at length the reign of justice begin also for the animals? When will the precepts of our Divine Redeemer be so universally and deeply engrafted in the breast of man, that he will learn not only to love his brother but to extend his charity to every creature dependent on his power?

CHAPTER XXVIII.

MAN.

Pre-eminence of Man—His Greatness and his Weakness—The Brain of Man—The Telegraphic System of the Nerves—The Optic Nerve—The Organs of Hearing, Taste, Smelling, and Touch—Spinal Nerves—Motile Nerves—Sympathetic Nerves—The Human Hand—Its Harmony with the Intellectual Faculties of Man—Differences in the Limbs of the Ape and Man—Man's Upright Walk—His Privileges and his Duties.

The star-spangled heavens, the brilliant sun, the magnificent ocean with its constantly-returning tides, the numberless plants which ornament our earth, and the vast hosts of animals that find their subsistence upon her teeming surface, are all most splendid monuments of the Creator's power; but, as far as we are able to probe the secrets of the universe, Man is beyond all doubt the most wonderful, the most perfect of His works. For the stars wander through the heavens unconscious of their own magnificence; the sun knows not that but for him countless beings would sink into night and death; the ocean is blind to the majesty of his rolling waves, and deaf to their awful music; the flower spreads its sweet odours, or enrobes itself in every hue of the rainbow without any conception of its loveliness; the animal's feelings are confined to the present moment with its joys or sorrows: but the eye of man darts into the boundless future and the illimitable past, and the vast range of his mind embraces the universe, and rises from the visible world to the throne of the invisible God—from whose unspeakable goodness, wisdom, and power all those stupendous works have emanated! And it is not only the infinite external world that lies open to the mind of man; he also penetrates into the mysteries of his own being, watches attentively all the movements of his soul, and carries in himself the judge of all his actions, thoughts, and sensations.

A wonderful organ—the brain—is the seat or the instrument of the astonishing mental faculties of man, the link or mediator between our body and our soul, between the material and the immaterial, the external and the internal world. Here resides our memory, which so marvellously resuscitates the past; our fancy, whose constantly-changing pictures enliven and beautify our life; our judgment, which penetrates the mysteries of Nature, and weighs causes and effects; our sensibility, with its multifarious passions and feelings; our will, whose commands flash with electric speed through our whole body, or oppose a strong barrier to our inclinations.

How small is our brain, and yet how immense the sphere of its activity! How many thoughts and pictures, and resolutions and sensations, cross it in the space of a single day! And as on the bosom of the sea, sunshine and shade, and storms and calms, are perpetually alternating, thus also this restless organ, in which so many divine powers and noble aspirations are blended with so many base desires, is the scene of perpetual changes!

And how various its scope and bias in different individuals: in the assassin, planning his midnight murder, so that the blow may not recoil upon himself; or in a Newton, meditating on the laws that govern worlds; in the sober man of business, who carefully shuts out all fancy from his reasonings; or in the poet—

> Whose eye in a fine frenzy rolling,
> Glances from heaven to earth, from earth to heaven!

Who can paint the happiness, the bliss, that finds room in the little human brain; or the nameless sorrow, the comfortless despair, which there takes up its abode?

An organ so wonderfully gifted for the extremes of light and shade may well be called a little world in itself; but as the most costly vases are most liable to injury, thus also a trifle suffices to destroy the faculties of this masterpiece of creation. While wafted along by the full-tide of his successful ambition, or soaring aloft in the highest flight of his fancy, or plunged in his deepest meditations, or fascinating his hearers by the noblest flow of his eloquence—the statesman, the poet, the philosopher, the orator, is suddenly struck with apoplexy; and that masterly policy, that blooming imagination, that profound wisdom, that

sublime power of speech, which raised their gifted possessors so high above the vulgar crowd, are blotted out at once; for though death may delay to strike its victim, yet the mental powers are generally laid low for ever, and the object of universal admiration or envy lives but to be pitied. Thus in the brain, both the strength and the weakness of man appear in their fullest light; and, should his vast superiority over the animal creation, his exalted position as lord of the earth, awaken his pride, the rapidity with which an accident—a blow, a concussion, the rupture of a bloodvessel—may precipitate him from the pinnacle of his intellectual life may well teach him to be humble.

We know with the utmost certainty that the brain is the seat, the physical or material organ, of our intellectual faculties; but the internal mechanism of this admirable laboratory of thought and feeling is totally unknown to us.

We know that from the fishes and reptiles upwards, through the long series of birds and mammalian quadrupeds to man, the brain increases in size and development with the growth of intelligence, but science has not yet been able to sound the depth of its recesses.

The knife of the anatomist shows us no remarkable difference between the brain of the greatest and of the lowest of mankind; the chemist finds in every cerebral organ the same substances; and the microscope sees everywhere the same inextricable labyrinth of delicate fibres and intermingled globules, that unite and separate, and appear and disappear again in a formless mass. In one word, the brain so well conceals its secrets that their discovery seems totally impossible, and man may perhaps sooner be able to fathom the structure of the universe than that of the mysterious instrument of his own thoughts and sensations.

Inclosed in a shell of solid bone, and thus shielded from many dangers, the brain receives the impressions of the external world, or reacts against them through the agency or channel of the nerves—whose delicate filaments, ramifying through the whole body, either transmit its orders or act as faithful messengers of what is going on without. The nerves which communicate external impressions to the brain are called sensitive nerves, and of these the optic nerves command the widest

range of observation. Originating in the optic thalami, two round eminences situated to the right and left at the basis of the brain, they cross each other; and then each of them, proceeding to the eye for which it is destined, spreads out into a membrane gifted with marvellous powers—a truly magical mirror, which, assisted by the most wonderful optical contrivances, exhibits to the mind a faithful picture of the external world in all its infinite varieties of form and colour. On this small surface a vast prospect reflects itself with photographic distinctness, and our mind receives the impression, and translates immediately the little picture into the vast reality, and steps, as it were, out of its own frame into the wide space submitted to its view. The charms of a splendid landscape, the magnificence of the ocean, the awful grandeur of the heavens, may well strike us with admiration; but if custom had not made us too familiar with the inexplicable wonders of our own organisation, we should be no less enraptured with the amazing instrument which thus wonderfully reveals to us the beauties of the external world. What a surprising delicacy of sensation! how perfect a structure! and how admirable the strength of the healthy eye, before whose crystal mirror picture follows upon picture for hours together, without its ever being fatigued, or losing anything of the sharpness of its perceptions!

From another part of the basis of the brain proceed two other nerves, differently though no less admirably gifted. These penetrate on each side into a cavity of the skull, forming the hard solid case of a most curiously-constructed apparatus, which every vibration of the air sets into a corresponding motion. Here, in a bony structure very similar to a snail's shell, the innumerable filaments of the acoustic nerves expand into a spiral membrane, which, stimulated by the vibrations of the sounding

Expansion of the Acoustic Nerve. (Magnified.)

apparatus, instantly communicate the impressions they have received with the most admirable precision to the brain.

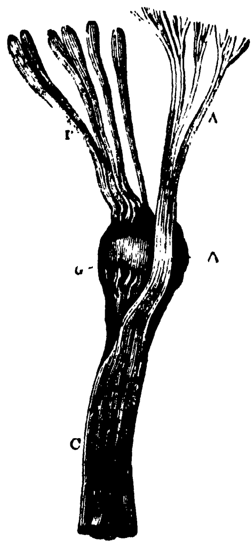
While the optic nerve holds up to us the magic mirror in which Nature appears in all her beauty, the auditive nerve opens to our perception the wondrous realms of sound. The undulating atmospherical vibrations produced by the voices of a choral band, or by the instruments of an orchestra, strike its delicate membranes and awaken musical sensations, which, transmitted to the soul, attune it to joy or to sorrow, rouse it to martial ardour, or exalt it to feelings of the deepest piety.

In a similar manner the olfactory and gustative nerves, proceeding from other parts of the brain, spread out like pieces of tapestry over the nasal cavities, or over the surface of the tongue and palate, and, stimulated by the smelling gaseous particles that may be mingled with the air we respire, or by the sapid liquid substances we swallow, communicate their various impressions to the brain.

While the senses of vision, hearing, taste, or smell thus each depend upon a single pair of nerves seated in the brain, and confined to a comparatively narrow space, the sense of feeling extends over the greater part of the body. The face, the mouth, the nasal cavities feel by means of a pair of nerves proceeding, like those already mentioned, immediately from the brain; but all the other sensitive nerves that ramify over the body, though communicating with that central organ, first pass through the spinal marrow, whose posterior columns they form, and which runs like a thick cord from the brain downwards through the spinal canal. From the spinal marrow they then emerge at regular intervals in thirty-one pairs, which, branching out, each supply a certain part of the body with the necessary power of feeling external objects. In those parts where a greater nicety of touch or acuteness of sensation is unnecessary, or would have been more irksome than useful, the sensitive fibres are more thinly scattered—as, for instance, on the back; or they may even be entirely wanting, as in many internal parts of the body. Their chief distribution is in the skin, where they not only enable us to distinguish many of the physical properties of external objects—such as their degree of solidity, their weight, the soft or rugged of their surface—but preserve us, moreover, like trusty

sentinels, from countless injuries. For how many dreadful wounds would be constantly ensuing if the sensation of pain communicated by the cutaneous nerves to the brain did not warn us to be careful, or teach us by repeated experiences to guard our movements!

Thus the senses connect us in a truly marvellous manner with the various phenomena of the external world; but the brain is meant to be not merely a recipient of sensations, but also to impel our limbs to action; and this highly important function is likewise performed through the agency of peculiar nerves, which partly emerge from various small orifices at the basis of the skull, partly run through the spinal cord whose *anterior* columns they form. From these their fibres emerge, in a similar manner with the sensitive filaments, in thirty-one pairs, which, soon after their emission, commingle with the corresponding sensitive fibres, and form a compound nerve, which distributes its branches to the muscles, or to the integuments of a part of the body or the limbs. Thus each spinal nerve has two roots, a sensitive and a motile one, and each root is composed of a large number of independent fibres. The sensitive filaments, destined to lead impressions to the brain, and utterly incapable of executing its orders, chiefly terminate in the skin; while the motile filaments, destined to transmit commands from the brain, and utterly insensible, terminate exclusively in the muscles, which at their bidding contract or relax their hold.



Origin of a Spinal Nerve.
(Magnified.)

A. Anterior root; P. posterior root G. ganglion on the posterior root. C. compound nerve resulting from the commingling of the fibres of both roots.

Thus each nervous filament has its peculiar task to perform, and the salutary effects of the division of labour are nowhere more apparent than in the economy of our body. What a dreadful confusion if the optic nerve, for instance, had to be the mediator of feeling, or if the motile nerves had to perform the functions of smelling or tasting!

But by the wisdom of Providence the optic nerve can only see, the auditive nerve only hear, the sensitive nerve only feel, the olfactory nerve only smell, the gustatorial nerve only taste, the motile nerve only move; and thus as each messenger has only one thing to do, he cannot possibly interfere with the work of his neighbour, and all goes on in the most beautiful order.

Every nerve of our body is ultimately connected with the brain, but not every nerve obeys its mandates, or communicates to it distinct sensations. For all the vegetative functions of our body, such as the digestive process, the circulation of the blood, the secretions of the glands, are under the control of a peculiar system of nerves, which, though connected with the brain, is in a great measure independent of that central organ, and executes its highly important task without our feeling it, or without our being able to control its execution.

Thus, as long as we are in health, our digestion goes on without our being aware of it; we cannot bid our heart to stand still; we breathe without paying any attention to the respiratory process; the liver and the kidneys secrete without our perceiving their activity in the least. This is evidently a most beneficial arrangement, for how could our mind have found time or repose for reflection and mental improvement—how could it properly have fixed its attention on the outer world, if the brain, besides its actual tasks, had also been burdened with the direction of our internal economy?

But as soon as our organs become affected with disease, then the slumbering sympathies of our brain are called forth; then sensations of pain, awakening in parts of whose existence we have but a dim feeling, inform us that the wonderful mechanism of our body is out of order, and claims repose or medical assistance.

In spite of his vast mental superiority, man would have constantly remained a most helpless and miserable creature if his limbs, like those of the animals, had been merely made to serve for motion, for climbing, or digging, or as offensive and defensive weapons. But Providence, which gave man an intelligence befitting him to be the master of the earth, could not possibly have left him without the mechanical means necessary for asserting his dominion; and thus the anterior extremities, which

in the animals only serve for locomotion, or for the prehension of food, or for aggressive or defensive purposes, have been raised in his economy to be the instruments of higher purposes, and formed so as to be able to execute the orders of a rational judgment.

The arms of the apes or anthropomorphous monkeys (as they are termed in systematic phraseology) have indeed some resemblance to those of man; but a closer inspection of their internal structure soon brings to light a considerable difference. Thus the lateral movements of the forearm, which produce the pronation and supination of the hand, are far more confined even in the highest apes, who are incapable of turning the palm of their hand completely outwards, and of extending their thumb to a considerable distance. The thumb of the human hand can be brought into exact opposition to the extremities of all the fingers, whether singly or in combination; whilst in the apes the thumb is so short, and the fingers so much elongated, that their tips can scarcely be brought into opposition, and the thumb and fingers are so weak that they can never be opposed to each other with any degree of force. While man is able to move each finger separately, those of the ape can only be bent or extended conjointly, since the small flexor and extensor muscles of the individual fingers existing in the human hand are either entirely wanting or joined together. Hence, although admirably adapted for clinging round bodies of a certain size, such as the small branches of trees, the extremities of the apes can neither seize very minute objects with such precision, nor support large ones with such firmness, as are essential to the dexterous performance of a variety of operations for which the hand of man is beautifully formed.

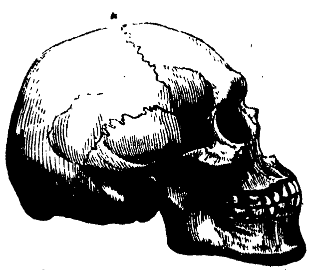
His naked skin leaves man defenceless against the inclemencies of the weather, against heat and wind; but the dexterity of his hand amply makes up for this deficiency, and spins and weaves an immense variety of dresses, which it adorns, moreover, with all the colours of the rainbow, so as to combine the useful with the agreeable. His weak arm is incapable of coping with the brutes of the forest, but with steady hand he hurls the deadly arrow, or sends the far-reaching bullet through the air. Though a very imperfect swimmer he overtakes all the denizens of the ocean, pursues them into their remotest

haunts, strikes them with his harpoon, or entangles them in his fatal net.

His hand is not fossorial, like that of the mole, but deep into the bowels of the earth he sinks his shafts, and makes himself master of her hidden treasures. With the spade and the plough he loosens her surface, and forces her to pay him the rich tribute of her harvests. In vain do rivers and mountains throw their obstacles in his way—he spans his bridges over the stream, or drives his tunnels through the rock. In vain the deeply-rooting forest strives to take possession of the soil—his sharp axe strikes the giants of the woods, and levels them with the dust.

And the same hand which gives him such power over the remainder of creation fixes upon the canvas all the beauties of Nature with a truth of colouring equal to reality itself, transforms a rough block of marble into the divine form of an Apollo, or 'wakes to ecstasy the living lyre.'

As the anterior extremities of man are adapted for prehension alone, while the posterior limbs serve exclusively for support and progression—an organisation which belongs to him alone—thus also he is the only mammal formed for an erect attitude. His head rests upon his spinal column in such a manner that he can maintain it in an upright position for a whole day with so slight and involuntary an effort that no fatigue is produced by it, while that of the orang, having its centre of gravity inclining to the front, would require the constant action of muscular power to keep it upright. The position of the face immediately beneath the anterior portion of the cranial cavity, so that its front is nearly in the same plane as the forehead, is peculiarly characteristic of man; for, as we see in the adjoining illustrations, the cranium of the orang is entirely posterior to and not above the face. This projection of the apeish muzzle is another evidence of want of adaptation to the erect posture, whilst the want of prominence in the face of man shows that none but the erect position can be natural to him. For, sup-



[illegible] ~~Human~~ Skull.

posing that, with a head formed and situated as at present, he were to move upon all-fours, his face would then be brought into a plane parallel with the ground, and as painful an effort be required to examine with the eyes an object placed in front of the body, as is now necessary to keep the eyes fixed on the zenith. Then also the nose would be almost incapacitated for receiving any other odorous emanations than those proceeding from the earth, or from the body itself, and the mouth could not touch the ground without bringing the forehead and chin also in contact with it.

Skull of the Orang-œtan.

Though the apes are able to adapt the inclination of their heads without much difficulty either to the horizontal or to the erect posture, yet the natural position in the highest among them is unquestionably one in which the spinal column is inclined; the body being partially thrown forward so as to rest upon the anterior extremities, and in this position the face is directed forwards without any effort.

The different formation of the pelvis in man, and in the apes likewise, shows that, as the former has been made for an upright walk, so the latter are condemned by nature to a grovelling position; for while in man it is peculiarly broad, and curving forwards and upwards, so as to give a wide basis of support to the abdominal viscera, it is much longer and narrower in the apes. The human foot is, in proportion to the size of the whole body, much larger, broader, and stronger than that of the ape; its short stiff toes enable it to plant itself more firmly on the ground, and its sole is concave; so that the whole weight of the body falls on the summit of an arch, of which the heel-bone and the middle part of the foot anterior to the toes form the two points of support. This arched form of the foot and the habitual contact of the heel-bone with the ground are peculiar

to man alone; for all the apes have the heel-bone small, straight, and more or less raised from the ground, which they touch, when standing erect, with the outer side of the foot only. The longer and more moveable feet and toes of the apes enable them to serve as more efficient prehensile organs, but this advantage is obtained at the cost of their capacity to sustain the weight of the body when it simply rests upon them.

Many other anatomical details might be pointed out to show how man's superiority of mind has been made to harmonise with its material instruments, while the structure of the ape corresponds with this animal's inferior intelligence; but, not to fatigue the reader with what might be considered a superfluous minuteness, I shall merely mention how strikingly the vast difference between the two shows itself in the muscular apparatus of the face. In man we find a number of distinct and separately moveable facial muscles, which, by their infinite variety of action, are able to give a rapid and faithful picture of all the various emotions that cross the soul, even as the surface of the sea reflects each passing cloud; while in the ape the facial muscles, being far less individualised, are restricted to the gnashing of the teeth, or to the pointing and shutting of the mouth; so that the animal is only able to cut a few disgusting grimaces, while numberless shades of passion, emotion, and thought are all mirrored in the expressive countenance of man!

Thus we see a deep chasm separating our race even from those animals which approach it the nearest in their outward form; for though the ape is undoubtedly capable of short and simple processes of reasoning or of imagination, yet the range of his intelligence is poor indeed when compared with that of the human mind.

Man alone of all created beings earnestly pursues a higher aim; he alone possesses an innate moral law; he alone is capable of self-improvement, and preserves his intellectual conquests for the benefit of his posterity; he alone rises from this material earth into the immaterial regions of the spiritual world; he alone has the consciousness of a future state! And for what purpose have these eminent faculties been awarded to man? Why has the vista of a brighter futurity been thus opened to his gaze? Is he to rest satisfied with merely providing for his bodily

wants? Then, indeed, the animals of the field are far better off than he, for they are able to find their food with far less trouble, and know no care for the morrow.

But no; the nobler faculties of man evidently point out to him a more exalted path and higher duties. Self-improvement, self-ennoblement, emancipation from the bonds of sensuality and egotism—these must be the chief aims of his existence, and prepare him for that more perfect state of being of which he bears the promise in his breast, and which has been revealed to him by the Divinity itself!

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LONDON
PRINTED BY SPOTTISWOODE AND CO.
NEW-STREET SQUARE